State of New Jersey
DEPARTMENT OF ENVIRONMENTAL PROTECTION
New Jersey Commission on Radiation Protection
PO Box 415
Trenton, NJ 08625-0415

JON S. CORZINE
Governor

LISA P. JACKSON
Acting Commissioner

January 18, 2006

The Honorable Jon Corzine
Governor
State of New Jersey
State House
PO Box 1
Trenton, NJ 08625-0001

Re: Recommendation Against Further State Funding of the Radiation and Public Health Project for Analysis of Radioactive Strontium-90 in Baby Teeth

Dear Governor Corzine:

In fiscal year 2004, the State of New Jersey appropriated $25,000 to the Radiation and Public Health Project (RPHP) to analyze levels of radioactive strontium-90 (Sr-90) in baby teeth. The results of their study, titled "Understanding Patterns and Trends of Radioactive Sr-90 in Baby Teeth of New Jersey Children with Cancer: A Report to the New Jersey State Department of Health and Senior Services", were presented to the Commission on Radiation Protection (Commission) on February 16, 2005. The RPHP contends that New Jersey children are more likely to have higher Sr-90 in their baby teeth if they have leukemia, if they were diagnosed before the age of ten, and if they lived in Ocean or Monmouth County (near the Oyster Creek Nuclear Generating Station).

The Commission and staff of the Department of Environmental Protection (DEP) have reviewed the RPHP's findings in the enclosed report. As you know, members of the Commission and staff of the DEP have extensive knowledge in the sciences, including physics, radiology, radiation biology, and medicine. The Commission and the DEP are well qualified to evaluate the scientific merits and methods of the RPHP.

The RPHP report concludes that no firm conclusions can be drawn because the limited number of teeth collected and analyzed make any comparisons statistically insignificant. The RPHP recommends further study and asks that the Commission support any RPHP request for further funding. The Commission and the DEP agree that no conclusions can be drawn from the RPHP study. However, the Commission and the DEP <u>do not</u> support further funding and believe that further study is not worth pursuing for the following reasons:

- The scientific validity of the data is questionable for reasons explained in Section 8.0 of the enclosed report.

- The predominance of environmental data shows no increase of Sr-90 in the environment.
- Conservative modeling demonstrates that the Sr-90 in baby teeth did not originate from OCNGS.
- It is highly likely that the Sr-90 present in baby teeth is from global fallout from nuclear weapons testing.
- There are no preventive strategies that could be employed to prevent accumulation of Sr-90 in teeth from global fallout. (A preventive strategy is the justification that RPHP uses to pursue further study.)

If, after reading the enclosed report, you or any State legislator have any questions, please feel free to contact me.

Sincerely,

Julie Timins MD

Julie Timins, M.D., F.A.C.R.
Chair, Commission on Radiation Protection

A Review of "Understanding Patterns and Trends of Radioactive Strontium-90 in Baby Teeth of New Jersey Children with Cancer: A Report to the New Jersey State Department of Health and Senior Services"

New Jersey Department of Environmental Protection
Radiation Protection and Release Prevention Element

January 2006

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New Jersey Department of Environmental Protection
Radiation Protection and Release Prevention Element
January 2006

1.0 EXECUTIVE SUMMARY

The Radiation and Public Health Project (RPHP) received an appropriation of $25,000 from the New Jersey legislature in fiscal year 2004 to analyze levels of radioactive strontium-90 (Sr-90) in baby teeth. The results of the RPHP analysis, titled "Understanding Patterns and Trends of Radioactive Sr-90 in Baby Teeth of New Jersey Children with Cancer: A Report to the New Jersey State Department of Health and Senior Services", were provided to the Cancer Institute of New Jersey in November 2004. The RPHP contends that New Jersey children are more likely to have higher Sr-90 in their baby teeth if they have leukemia, if they were diagnosed before the age of ten, and if they lived in Ocean or Monmouth County (near the Oyster Creek Nuclear Generating Station [OCNGS]).

In a letter dated February 18, 2004 (Appendix A), the Commission on Radiation Protection (Commission) provided advice to Governor McGreevey regarding the quality of research conducted by the RPHP. The Commission offered its assistance to the Governor in evaluating the results and conclusions of reports generated by the RPHP, also called the Tooth Fairy Project, and recommended against any further support.

At a Commission meeting on February 16, 2005, the RPHP presented the findings of the State-funded study and provided several reports, papers and data summaries, all related to Sr-90 in children's teeth. The RPHP strongly urged the Commission to support their request for funding to continue their investigations.

The Commission and the Department of Environmental Protection (DEP) have reviewed the RPHP's findings from a number of perspectives including the reliability of the measurements of Sr-90 in teeth, an assessment of the reported data, the scientific validity of the statistical methods employed in the investigation, and a bounding calculation of the fate of Sr-90 in the environment from OCNGS. Data from the DEP, the US Environmental Protection Agency (EPA), and the US Nuclear Regulatory Commission (NRC) were reviewed in the context of the presentation given by Mr. Joseph Mangano at the Commission meeting. Mr. Mangano is the lead researcher at the RPHP.

Mr. Mangano contends that the study suggests a link between Sr-90 in teeth and cancer risk, and considers childhood or pediatric cancer cases found in Ocean and Monmouth Counties to be caused by radiation released from the nuclear power plant. However, as stated in the RPHP report, the study "has not conclusively shown that Sr-90 and other radioactive chemicals is a risk factor for childhood cancer." [1]

In his presentation to the Commission on February 16, 2005, Mr. Mangano asserted that levels of Sr-90 are rising in the environment and that radioactive effluents from nuclear power plants are directly responsible for this alleged increase. This assertion is inconsistent with results of monitoring that takes place routinely around New Jersey's nuclear power plants. The DEP's review of state and federal environmental monitoring data found no measurable Sr-90 concentrations in collected air samples. Review of EPA's Environmental Radiation Ambient Monitoring System, RadNet (formerly known as ERAMS) data indicates that there is no increase in gross beta concentrations in precipitation, air, or milk for Trenton, New Jersey. Gross beta concentrations in precipitation and air, and Sr-90 concentrations in milk and drinking water from the EPA's RadNet Program, showed no regional differences. The DEP's environmental monitoring data, specific to Sr-90 analyses, were below detectable effluent concentration limits. The OCNGS fits the emissions profile of a typical U.S. boiling water nuclear power plant with total annual Sr-90 effluent release of approximately $1/1000^{th}$ of a Curie. Meteorological data demonstrate that the downwind direction from the OCNGS is variable. Only about 19% of the downwind direction is towards the north northwest and the north northeast which encompasses the Toms River area, a location which RPHP suggests needs further investigation. Therefore 81% of the time, based on documented meteorological conditions, radioactive effluent would not be transported towards Toms River.

A set of scoping calculations were performed by John Mauro, Ph.D., a Commission member. Dr. Mauro assumed worst case scenarios for the fetal, infant-milk, drinking water, and inhalation pathways. The results of these calculations show that OCNGS does not release enough Sr-90 to account for the amount seen in the teeth as analyzed by RPHP. In addition, Dr. Mauro's calculations demonstrate that the concentration of Sr-90 in teeth as detected by RPHP is consistent with what would be expected from global fallout due to atmospheric nuclear weapons detonations in the 1950's through 1970's. A detailed description of the calculations and assumptions is provided in Appendix B.

The RPHP Executive Summary states that no firm conclusions can be drawn at this time because the small number of teeth involved makes the comparisons statistically insignificant; and because a more refined method of "matching" each tooth donor with childhood cancer to a healthy child with similar characteristics in terms of age, race, gender, residence, and other factors, is needed if any conclusions are to be drawn. The Commission concurs that no conclusions can be drawn from the RPHP study. However, the DEP and the Commission believe that further study is not worth pursuing because:

- The predominance of environmental data shows no increase of Sr-90 in the environment;
- Conservative modeling demonstrates the Sr-90 in baby teeth did not originate from OCNGS;
- It is highly likely that the Sr-90 seen in baby teeth is from global fallout from nuclear weapons testing; and

- There are no preventive strategies that could be employed to prevent accumulation of Sr-90 in teeth from global fallout. (A preventive strategy is the justification that RPHP uses to pursue further study.)

2.0 SOURCES OF STRONTIUM-90 IN THE ENVIRONMENT

Sr-90 is a beta emitting fission product present in radioactive fallout (atmospheric nuclear weapons tests conducted in the 1950's and 1960's) and in the fission process of commercial nuclear power plants. It remains available in the environment for an extended period because of its 28.1 year half-life. It has been implicated as a causative agent in bone cancer and leukemia. Sr-90 mimics the behavior of calcium when ingested and becomes concentrated in calcified tissues such as bones and teeth. Sr-90 is known to increase the risk of bone cancer and leukemia in animals, and is presumed to do so in people. [2]

About 0.3% of the average annual radiation exposure of an individual in the United States is attributable to Sr-90 from all sources. Sr-90 does not occur naturally. About 99% of strontium in the environment comes from fallout from atmospheric nuclear weapons testing. Approximately 16.8 million curies of Sr-90 were produced and globally dispersed during atmospheric weapons testing. The second largest source of strontium present in the environment is the April 26, 1986 Chernobyl accident. Approximately 216,000 curies of Sr-90 were released. In comparison, on average, the total annual release of Sr-90 into the atmosphere from each U.S. nuclear power plant is typically 1/1000th of a Curie[3]. This is documented in annual effluent reports submitted to the NRC by the utilities. These reports are required to be available to the general public at local libraries, within ten miles of the operating nuclear power plants in New Jersey. The OCNGS effluent reports are available at the following locations:

Ocean County Library
101 Washington Street
Toms River, NJ 08753
http://oceancounty.lib.nj.us/default.htm

Lacey Township Municipal Building
818 West Lacey Road
Forked River, NJ 08731

3.0 PREVIOUS STUDIES EXAMINING HEALTH EFFECTS OF NUCLEAR FACILITIES ON POPULATIONS LIVING NEARBY

There are a large number of epidemiological studies that have examined the cause and effect relationship between nuclear power plants and possible health effects on populations living nearby.

In 1990, a study conducted by the National Cancer Institute (NCI) concluded that there was no convincing evidence of increased risk of death for people living in U.S. counties near 62 nuclear facilities, including 52 commercial nuclear power plants. Oyster Creek was one of the facilities included in the study. Excess risk of cancer death was compiled for 16 different types of cancer, including leukemia, and for five different age groups, including children under 10 years of age.[4]

Investigators from the University of Pittsburgh concluded that the radioactivity released during the Three Mile Island nuclear power plant accident in 1979 did not appear to have caused an increase in cancer mortality among people living within five-miles of the plant. Published in June 2000, the study followed more than 32,000 people. Continued follow-up of this group is planned.[5]

The American Cancer Society (ACS) concluded that, although reports about cancer clusters in communities near nuclear facilities have raised public concern, studies show that clusters do not occur more often near nuclear plants than they do by chance in other locations. The ACS goes on to say that ionizing radiation emissions from nuclear power facilities are closely controlled and involve negligible levels of exposure for nearby communities.[6]

4.0 RADIATION MONITORING OF NUCLEAR POWER PLANTS IN NEW JERSEY

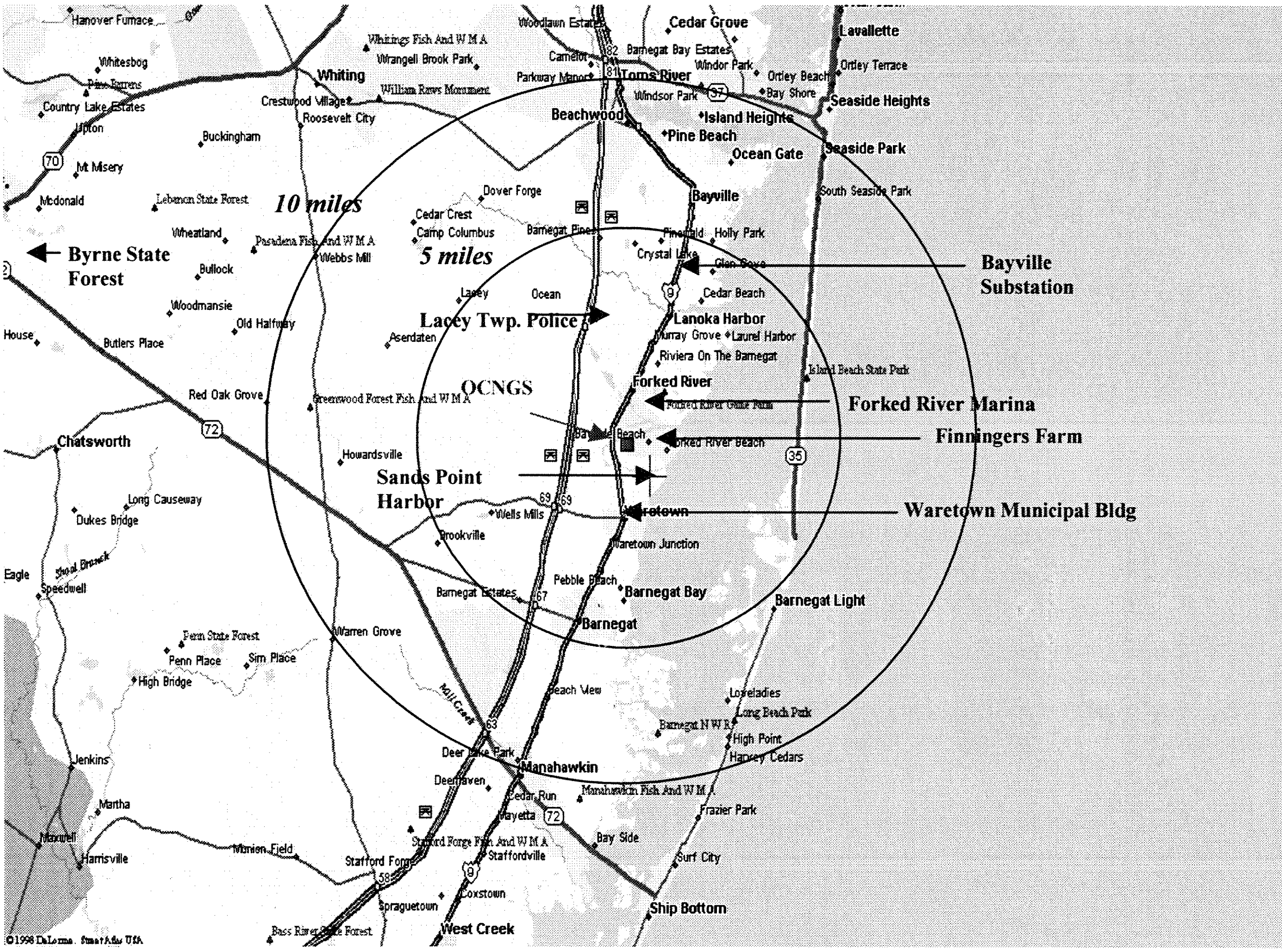
Significant environmental monitoring takes place around New Jersey's nuclear power plants. This monitoring includes state and federal programs, as well as federally mandated utility reporting.

4.1 NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION ENVIRONMENTAL MONITORING PROGRAM

The DEP's Bureau of Nuclear Engineering (BNE) independently monitors radiation in the environment outside the site boundaries of New Jersey's nuclear generating stations (Artificial Island and Oyster Creek). The BNE collects approximately 250 air samples, 200 water samples, 50 milk samples and 50 biological (fish, vegetables) and other environmental samples annually from both nuclear plant sites combined. Samples are analyzed through an independent certified contract laboratory.

The BNE maintains a network of six air sampling sites around Oyster Creek, as well as a background location at Brendan T. Byrne State Forest (formerly Lebanon), about 20 miles from the OCNGS plant site (Figure 1). Air samples are collected biweekly and are comprised of two parts. The first is an air filter, which is counted for gross beta radioactivity. This filter is then stored with other air filters collected from each individual site until the end of the quarter. At that time, all of the filters from each individual site are composited and analyzed for strontium-89, strontium-90 and gamma-emitting radionuclides. The second part of the biweekly sample is a charcoal canister, which is analyzed for gaseous iodine-131.

Figure 1
NJDEP Radiological Environmental Monitoring Program
Air Sampling Locations in the Environs Around the
Oyster Creek Nuclear Generating Station



4.2 US ENVIRONMENTAL PROTECTION AGENCY

The EPA's Environmental Radiation Ambient Monitoring System (RadNet) is a national network of monitoring stations that regularly collects air, precipitation, drinking water, and milk samples for analysis of radioactivity. Samples are sent for analysis to the Office of Radiation and Indoor Air's National and Radiation Environmental Laboratories (NAREL) in Montgomery, Alabama. RadNet, which has stations in each state, has been used to track environmental releases of radioactivity from nuclear weapons tests and nuclear accidents. It also documents background levels of environmental radioactivity. Data are made publicly available in quarterly reports titled "Environmental Radiation Data" published by NAREL. These reports are available on the EPA's Internet website at http://epa.gov/narel/erams/erdonline.html.

New Jersey falls within EPA Region 2, which also includes New York and the territories of Puerto Rico and the U.S. Virgin Islands. New Jersey maintains RadNet sampling stations listed by city: (1) Trenton, New Jersey - Air Particulate, Drinking Water, Milk; (2) Waretown, New Jersey - Drinking Water.

New Jersey's RadNet air samples are collected twice each week and sent to NAREL for analysis. A gross beta analysis is performed on each filter, and a gamma scan is done if the beta activity is greater than 1 picocurie per cubic meter (pCi/m^3). The screening level of 1 pCi/m^3 is a guideline EPA's NAREL uses to decide whether or not to determine the identity and activity of individual beta emitters in the sample, and does not correspond to any regulatory dose limit. Annual composites of the air particulate filters are analyzed for gamma emitting radionuclides. Drinking water samples are collected quarterly and sent to NAREL for analysis. The samples are analyzed for tritium quarterly, for gross alpha and beta on annual composite samples, for iodine-131 on one sample per year, and for Sr-90 on one-fourth of all the annual composite samples. All of the annual composite samples are also analyzed for gamma-emitting radionuclides. Milk samples are also collected quarterly and sent to NAREL for analysis. The samples are analyzed by gamma spectroscopy for iodine-131, barium-140, and cesium-137. Analysis for Sr-90 is done annually. Precipitation samples were collected monthly in Trenton, New Jersey and analyzed for tritium, gross beta, and gamma emitting nuclides up until 1996. Sampling was discontinued after 1996 due to equipment maintenance issues. NAREL no longer analyzes precipitation samples from the state of New Jersey.

4.3 US Nuclear Regulatory Commission

The NRC requires all nuclear power plant operators to monitor radioactive airborne and liquid discharges from the plant and to file a report of these effluent discharges annually with the NRC. The reports are available to the public on the NRC's website using their web-based library system, ADAMS, at http://www.nrc.gov. The power plant annual reports list the radioactive isotopes released, the quantity released and the estimated radiation dose to the public. The concentrations of radionuclides released into the environment from a nuclear facility are generally too low to be measurable outside the plant's boundary. The NRC conducts routine inspections of the radioactive gaseous effluent treatment and monitoring systems as part of their reactor oversight program. There is an inspection to determine if flow rates are consistent with reported values, to review instrument calibrations performed since the last inspection, and perform a walk down of systems to determine calibration compliance. The last NRC inspection of OCNGS was in October 2004.

5.0 ASSESSMENT OF DATA

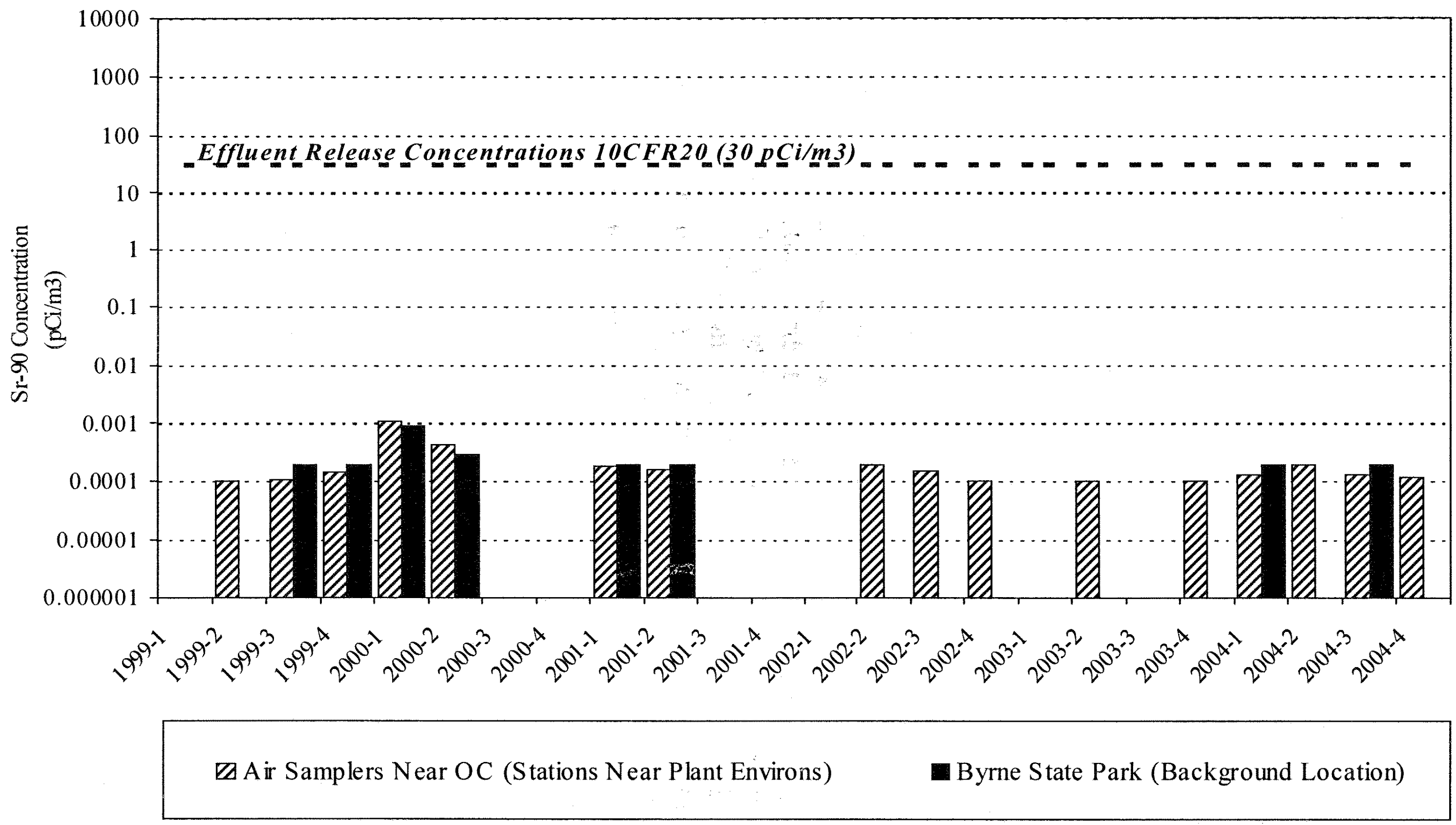
5.1 NJ DEPARTMENT OF ENVIRONMENTAL PROTECTION

5.1.1 Strontium-90 Concentrations in Air, Analysis Results for the Environs of the OCNGS – 1999 to present

Due to concerns expressed by the public, the DEP instituted quarterly analysis of Sr-90 in air samples in 1999. NRC Regulatory Guide 1.21 [7] also recommends quarterly analysis of strontium on composites of all air filters collected from air sampling sites. The samples are collected and composited, and analyzed quarterly. The average minimum detectable concentration (MDC) for these analyses is 0.002 pCi/m^3. The MDC is the smallest concentration of radioactivity in a sample that can be detected with a particular degree of statistical confidence. The MDC will change depending on the method of analysis, the specific analyte, the counting time, and other factors. (See the Glossary for a more detailed explanation.) Samples collected and analyzed by the DEP indicate no measurable Sr-90 concentrations in air. Sr-90 readings are mostly below the MDC and comparable to the DEP's background location. Any results above the MDC were one ten-thousandth of the NRC's allowable discharge limits (Figure 2). With the re-introduction of Sr-90 analyses, missing quarterly data was due to various reasons, including transitioning from one laboratory contract to the next, and mechanical failures of the air sampling equipment. Mechanical failures were corrected with the purchase of new equipment in 2003. Other reasons for missing data are external factors such as power failures.

Figure 2

NJDEP Data
Strontium-90 Concentration in Air Particulate Composites
Quarterly Analysis Results for Environs of Oyster Creek Generating Station
Calendar Year 1999 Through Present



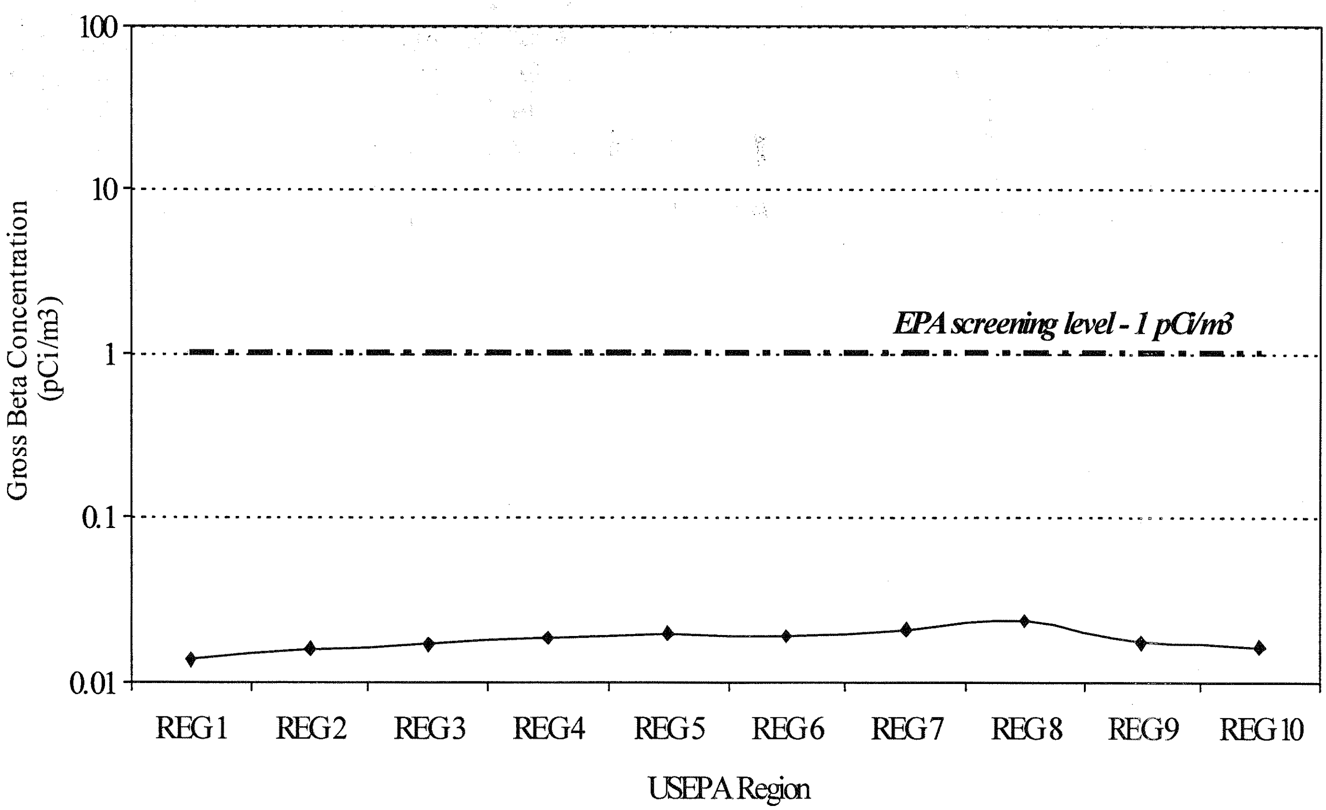
5.2 US ENVIRONMENTAL PROTECTION AGENCY

5.2.1 Average Concentration of Gross Beta in Air in the US by EPA Region - (1981-2003)

Figure 3 depicts the average gross beta concentration in air for each of the USEPA regions for the time period 1981 through 2003. New Jersey is in EPA Region 2. Results show that the average gross beta for Region 2 (0.0159 pCi/m^3) is below the average for almost all other regions across the country (0.0180 pCi/m^3). The highest average gross beta was found in the upper mid-west region. The gross beta concentrations reported would include Sr-90, a beta emitter, if it were present.

Figure 3

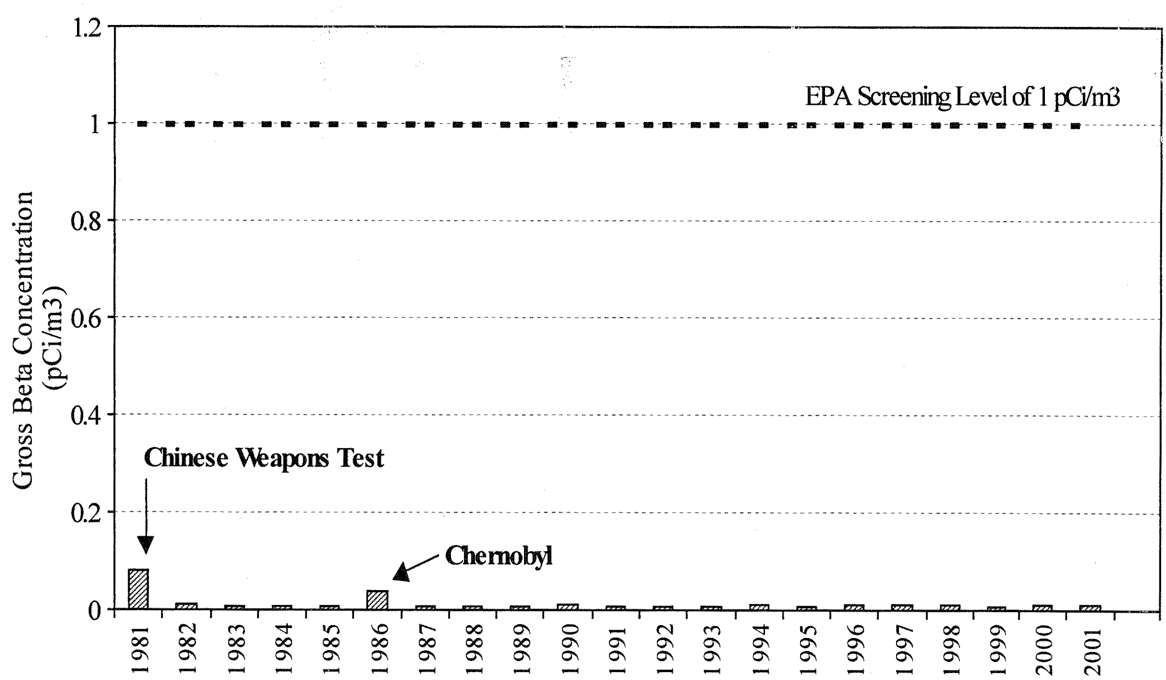
Average Gross Beta Concentration in Air in the US by EPA Region
1981 Through 2003



5.2.2 Gross Beta in Air for New Jersey RadNet Site, Trenton, New Jersey (1981-2001)

Figure 4 depicts gross beta in air measurements for Trenton, New Jersey for the time period 1981 through 2001, obtained from the EPA's RadNet Internet website. Results are several orders of magnitude below the EPA screening level of 1 pCi/m^3. Evidence of two radiological incidents can be seen on this graph: (1) the above ground nuclear detonations in China in 1981; and (2) the Chernobyl nuclear power plant accident in 1986 in the Ukraine. Higher than normal air particulate gross beta readings were seen in the RadNet data during these time periods as radioactive material found its way into the upper atmosphere's global circulation. In both instances, the gross beta concentrations were well below EPA's screening level.

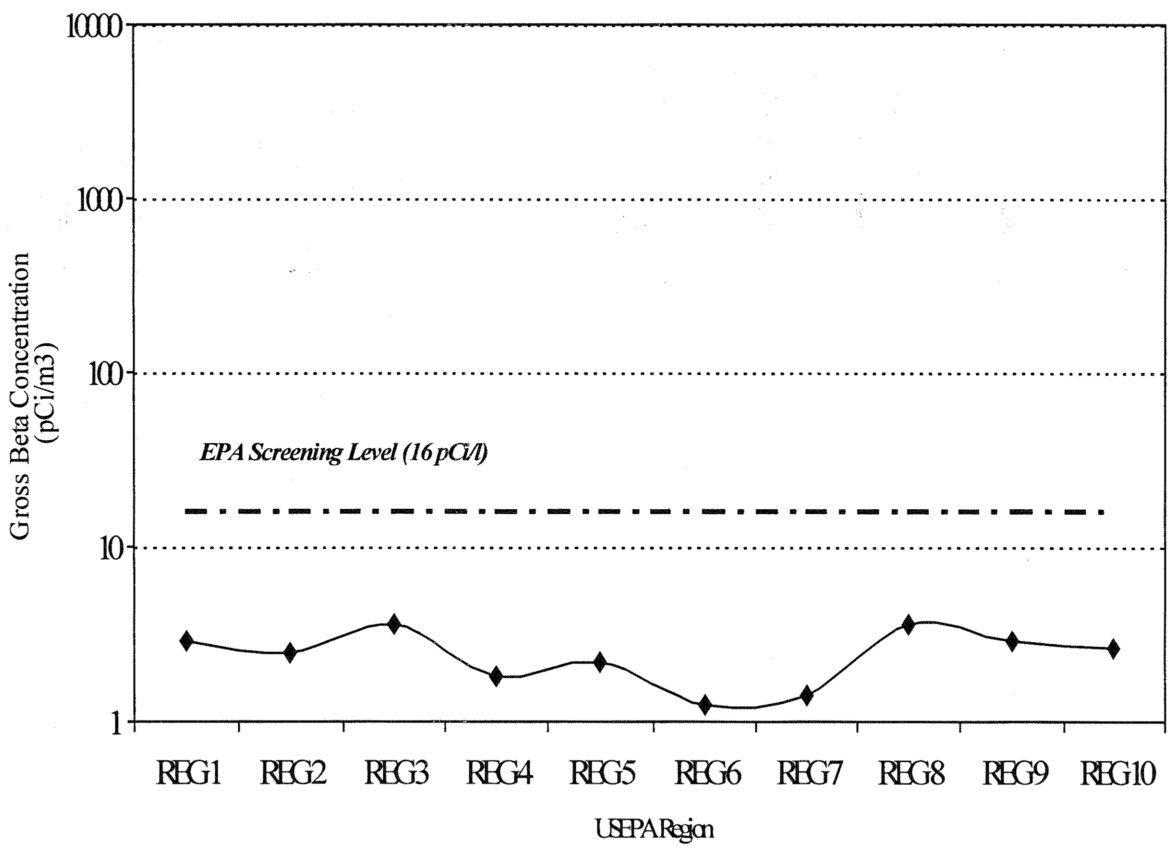
Figure 4
EPA RadNet
Average Gross Beta Concentration in Air
Trenton, NJ - 1981 to 2001



5.2.3 Average Concentration of Gross Beta in Precipitation in the US by EPA Region (1978-2003)

Precipitation samples are analyzed for gross beta concentration by the EPA's RadNet program. Results of the gross beta analyses include Sr-90, a beta emitter, if it is present. The results in Figure 5 indicate that all regional averages were below 10 pCi/L. Gross beta concentrations in the New Jersey region (Region 2) of 2.4 pCi/L were near the average seen throughout the nation. Historically, the highest average gross beta readings were found in the mid-Atlantic (Region 3) and upper mid-west (Region 8) regions.

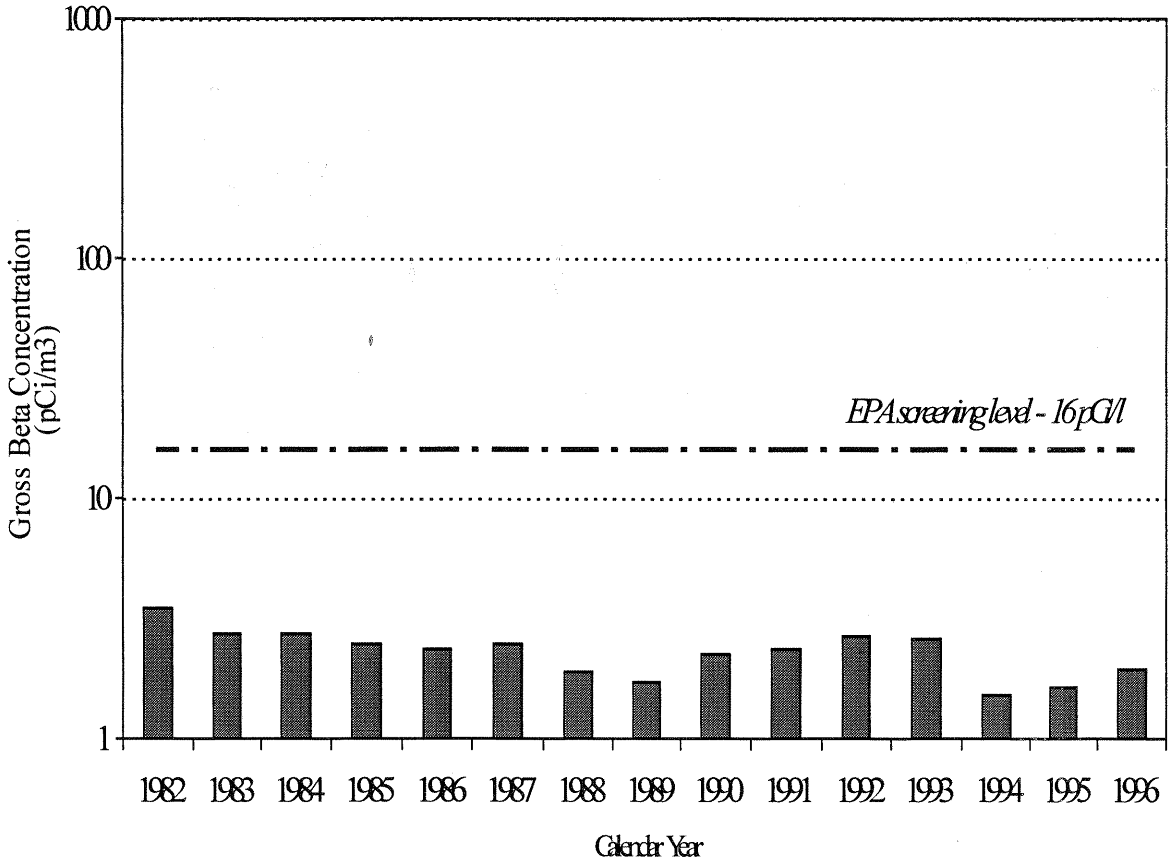
Figure 5
Average Gross Beta Concentration in Precipitation in the US by EPA Region
1978 Through 2003



5.2.4 Gross Beta in Precipitation for New Jersey RadNet Site, Trenton, New Jersey (1982-1996)

The RPHP study of November 2004 presents gross beta in precipitation data for New Jersey's RadNet site in Trenton for the time period of 1982-1993, stating an upward trend in the early 1990's. Figure 6 shows the results available from the more complete RadNet database for 1982 through 1996, the final year of collection. Consideration of the complete data set demonstrates that in fact there is no upward trend of gross beta activity in precipitation.

Figure 6
Gross Beta Concentration in Precipitation
Trenton, New Jersey
1982 Through 1996

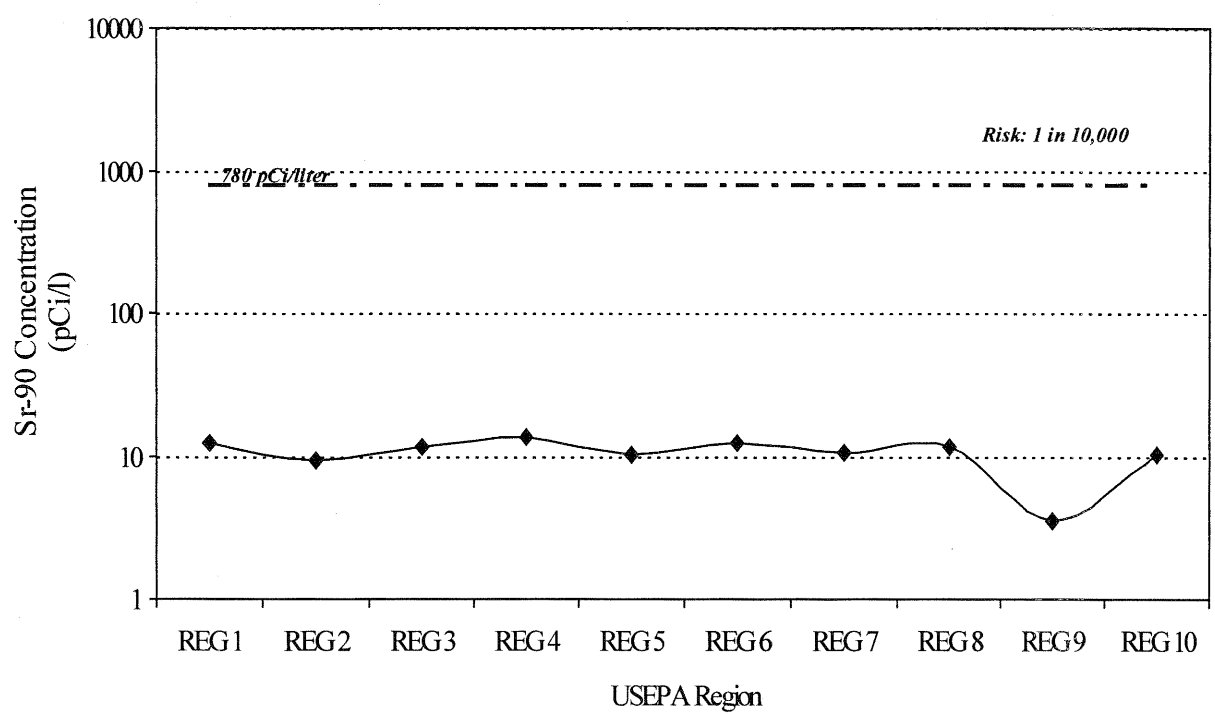


5.2.5 Average Concentration of Strontium-90 in Milk in the US by EPA Region (1960-2003)

Milk is sampled because it is a readily available food source consumed by a large portion of the population. Cow's milk is consumed in relatively large quantities by children over one year of age, and is a good indicator of radionuclides present in the environment. Although Sr-90 levels have decreased since atmospheric weapons testing was halted, Sr-90 is still detected.

Figure 7 shows that similar trends in Sr-90 concentrations exist in milk for all regions across the nation. The average historical Sr-90 in milk (1960-2003) for all EPA regions was 10.5 pCi/L. The average Sr-90 for Region 2 (including New Jersey) was below the national average (9.3 pCi/L). Historically, the southeastern region (Region 4) of the United States has the highest average Sr-90 in milk (13.4 pCi/l). All readings were well below EPA's acceptable risk level of 1 in 10,000 (780 pCi/L). Specific to the environs of the OCNGS, it should be noted that the New Jersey Department of Agriculture data shows that New Jersey produces only 12.6% of all milk consumed in the state. The other 87.4% comes from outside of New Jersey. There are no dairy farms within a 10-mile radius of Oyster Creek. The closest dairy farm is about 30 miles away (Burlington

Figure 7
Average Concentration of Strontium-90 in Milk in the US by EPA Region
1960 Through 2003



County, New Jersey).

5.2.6 Concentration of Strontium-90 in Milk for New Jersey RadNet site Trenton, NJ (1960-2001)

Figure 8 shows the concentration of Sr-90 in milk collected in Trenton, New Jersey. The concentrations are expressed in terms of picoCuries per liter (pCi/L) of whole milk. Since milk contains about 1.1 grams of calcium per liter, the Sr-90 concentrations in milk (expressed in units of pCi/L) can be divided by 1.1 to yield Sr-90 concentrations expressed in units of pCi of Sr-90 per gram of calcium in whole milk, which can be compared directly to the Sr-90 levels in teeth reported by the RPHP. The Sr-90 values reported in milk are virtually identical to the values presented in Table 3 of the RPHP report. Table 5-1 compares the average Sr-90 in the RPHP teeth (both molars and incisors) with the average Sr-90 in milk reported by the US EPA, in pCi of Sr-90 per gram of calcium. This data, combined with the fact that Sr-90 levels in milk are consistent throughout the country, demonstrates that the Sr-90 found in teeth are in agreement with what one would expect from weapons testing fallout. Slight differences (less than 1 pCi of Sr-90 per g of calcium) between the two data sets are likely due to uncertainties explained in Section 8 of this report.

Figure 8
Concentration of Strontium-90 in Pasteurized Milk in Trenton, NJ
(EPA RadNet Database)

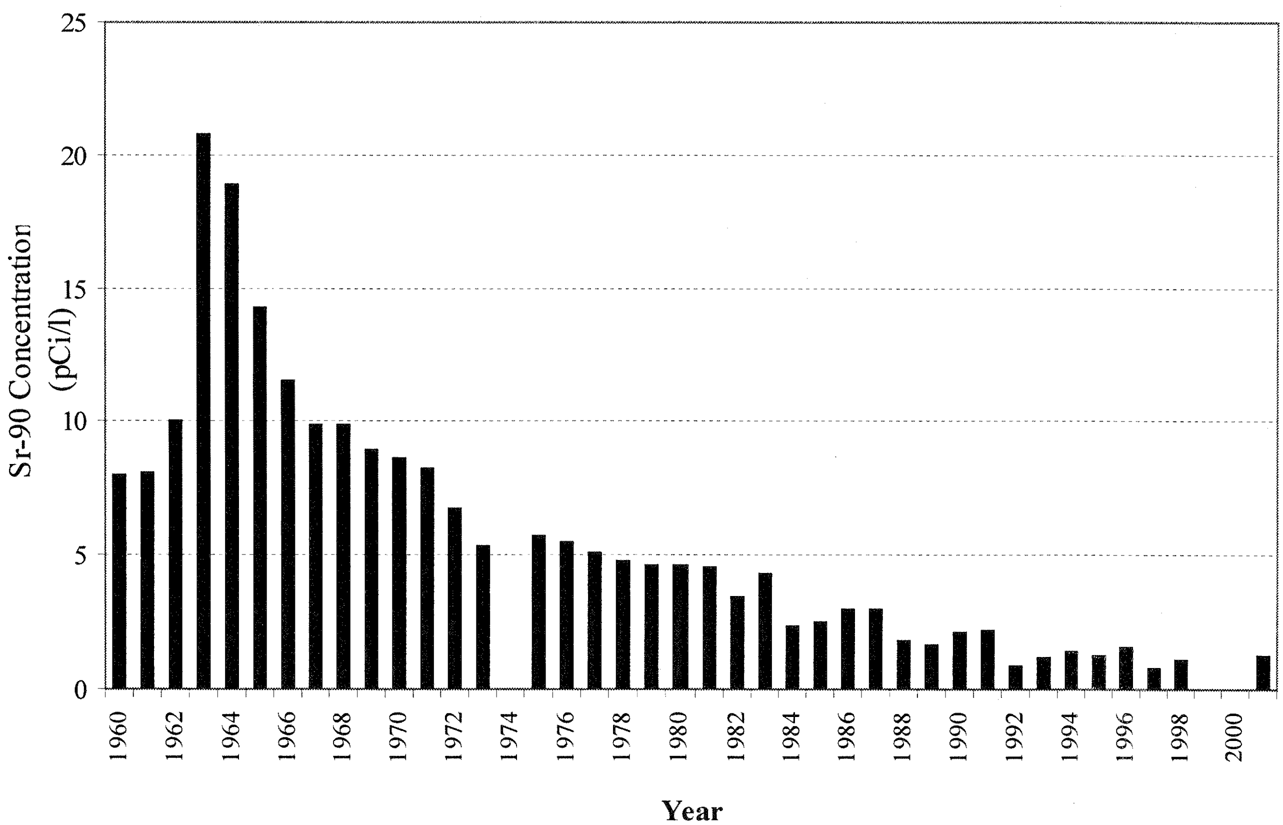


Table 5-1: Comparison of RPHP Sr-90 Levels in Teeth to US EPA Levels in Milk

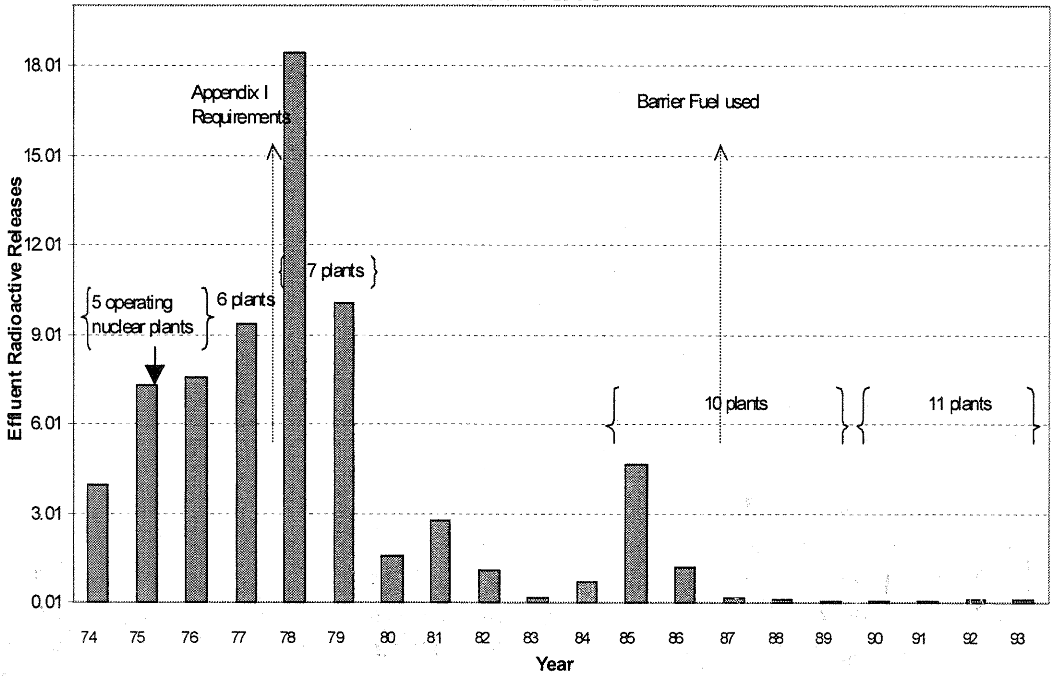
Years	*RPHP teeth data* *(Ave. pCi Sr-90 per g Ca)*	*Number of teeth analyzed*	*EPA Sr-90 in milk* *(Ave. pCi Sr-90 per g Ca)*
1980-1988	3.1	5	3.5
1989-1994	1.7	16	2.1
1995-1998	2.1	9	1.3

5.3 US NUCLEAR REGULATORY COMMISSION

5.3.1 Airborne Radioactive Emissions from Oyster Creek Nuclear Generating Station

The RPHP study presents data for airborne radioactive emissions in curies for 11 reactors in or near New Jersey for the time period 1987-1993. The data presented by Mr. Mangano indicated an upward trend of airborne radioactive emissions from 1990 to 1993. It should be noted that most of these reactors are located at least 50 miles from Toms River. Plant specific information for Oyster Creek is readily available in Annual Effluent Release Reports[8] submitted to the NRC by the licensee and available to the general public at local libraries. Figure 9 shows effluent radioactive releases over a nineteen year period. The number of nuclear power plants in proximity to New Jersey increased from five to eleven plants. During that time, new regulatory standards were developed by the NRC and implemented by nuclear power plant operators in the years following promulgation of the standards. These standards (Appendix I of 10 CFR 20) established reactor effluent exposure limits for members of the public. Additionally, barrier fuel was developed that improved efficiency and reduced discharges. There is no apparent trend in effluent release data during the time frame of Mr. Mangano's concern. As can be seen in Figure 9, any trend is insignificant compared to preceding years, and well below NRC's allowable limits for airborne radioactive emissions.

Figure 9
Radioactive Effluent Releases (I-131 and Particulates) in Curies for
11 Area Nuclear Plants
1974 - 1993



5.4 OYSTER CREEK NUCLEAR GENERATING STATION

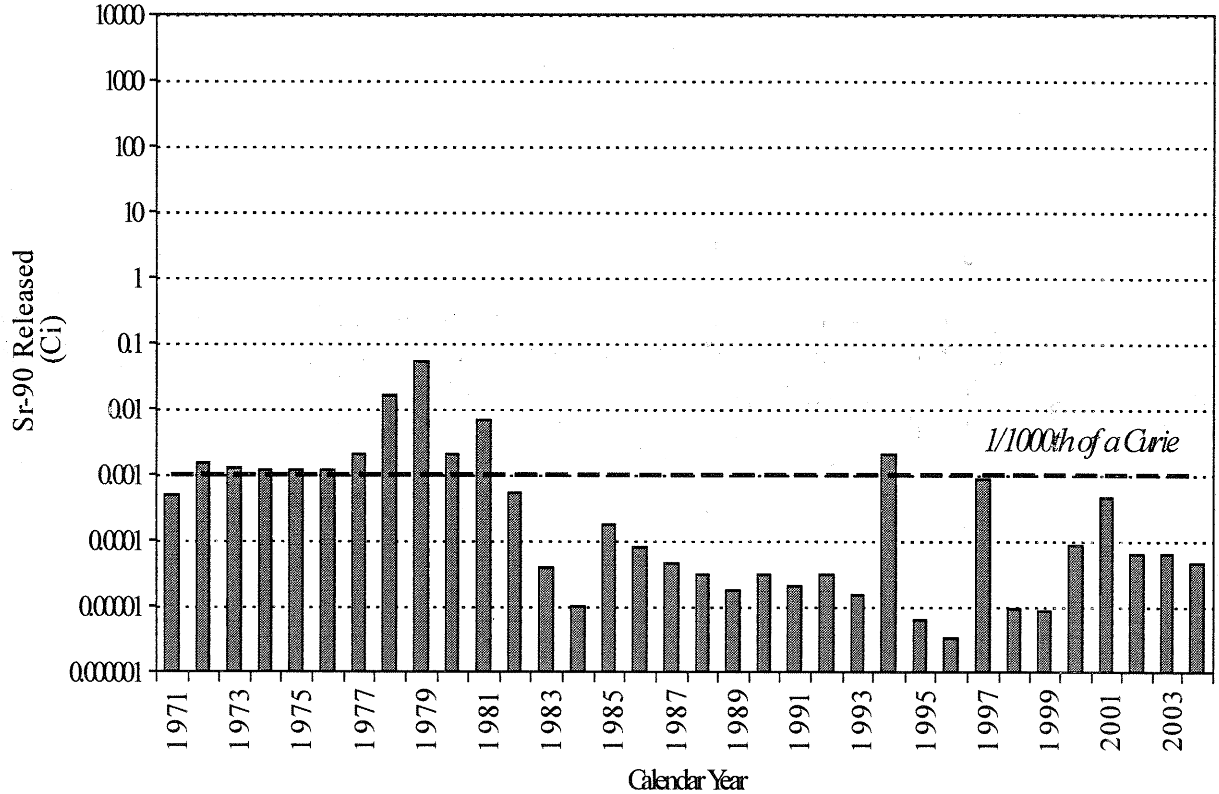
5.4.1 Gaseous Effluent Release of Sr-90, Curies of Activity

The data in Figure 10 is based on information obtained from the OCNGS Annual Radiological Effluent Release Reports. The OCNGS became operational in December 1969 and began performing individual isotopic analyses in 1971. From 1969 through 1970, releases were recorded as a single quantity. The data were obtained through monthly analysis of composites of air particulate filters. Contributions from the elevated stack and ground sources were combined to produce the annual release values.

As indicated in Figure 10, Oyster Creek fits the profile of a typical power plant with total annual Sr-90 effluent releases of approximately 1/1000th of a Curie. Strontium-90 levels in Oyster Creek's effluent stream are so low that they are below the USEPA screening criteria of 1 pCi/m3 in air.

Sr-90 is a byproduct of the fission of uranium contained within the fuel. Improvements in fuel integrity have helped reduce the amount of radioactive material released to the environment. Fuel leaks due to manufacturing defects can show up during the heating/cooling process of reactor operation. The use of barrier fuel, beginning in the early 1980's, has made the fuel less susceptible to leakage. At Oyster Creek, a boiling water reactor, the reduction in gaseous effluents is also due to the installation of an augmented offgas (AOG) system that reduces the amount of radioactive effluent prior to release to the environment. The NRC required many boiling water reactors to install AOG systems to meet the provisions of 10CFR50, Appendix I, promulgated in 1975. The AOG system at Oyster Creek went on-line in 1981.

Figure 10
Oyster Creek Gaseous Effluent Release
Strontium-90

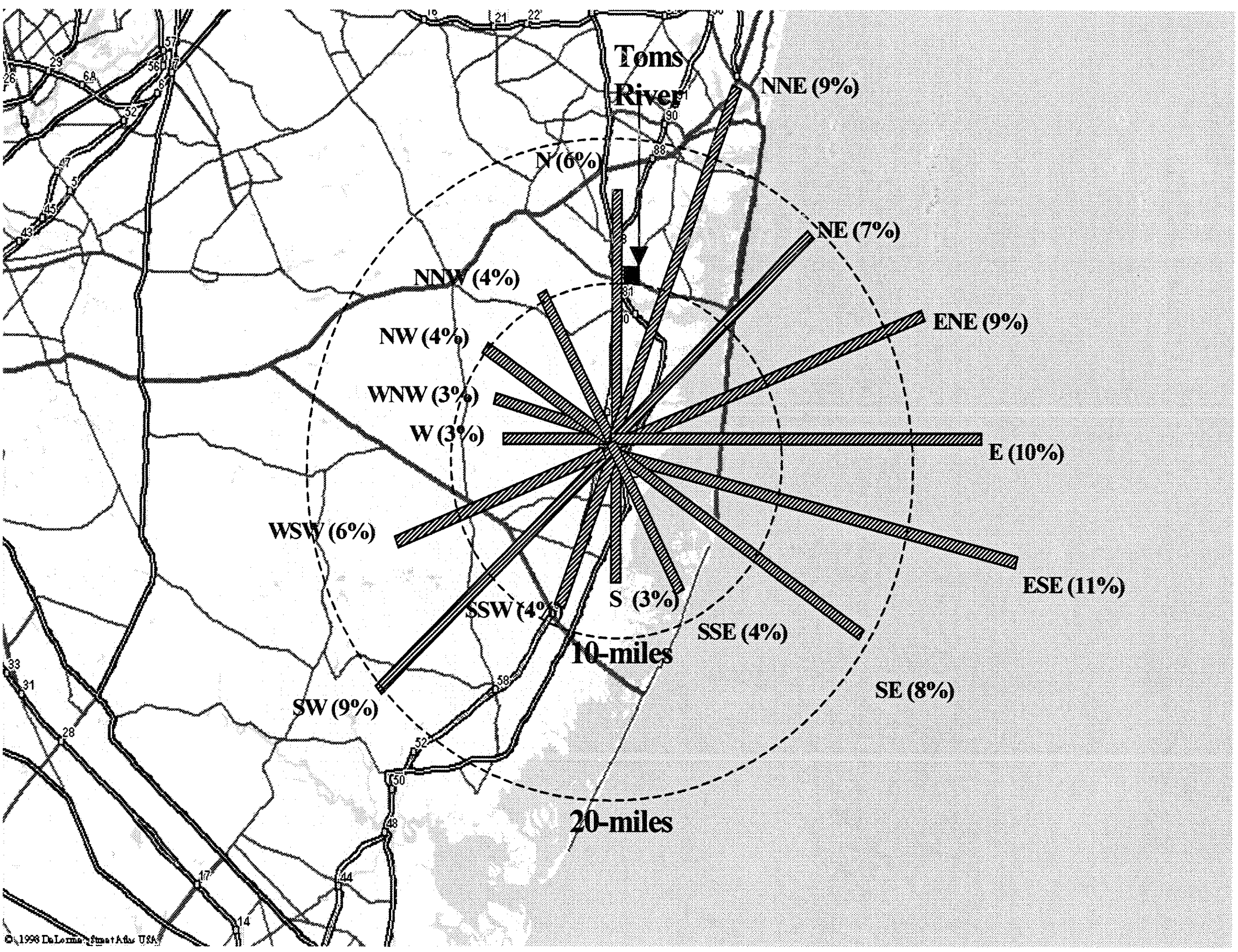


Source: Annual Radiological Effluent Release Report Data - Strontium-90 in Gaseous Effluent

5.4.2 Meteorological Conditions at Oyster Creek Nuclear Generating Station

Meteorological wind rose (a circular diagram showing, for a specific location, the percentage of the time the wind is from each compass direction) data demonstrates that the down wind direction from the OCNGS is variable as seen in Figure 11. Only about 19% of the downwind direction is towards the north-northwest (NNW) and the north-northeast (NNE) which includes the Toms River area, a location which RPHP suggests needs further investigation. Based on documented meteorological conditions, 81% of the time the wind is not blowing in the direction of Toms River. The potential for a concentrated distribution of radionuclides in Toms River is not supported by the area's meteorological conditions.

Figure 11
Wind Rose Data for the Environs of Oyster Creek Nuclear Generating Station
(Wind Direction Shown as "To")
Source: 2003 Meteorological Data - Forked River Meteorological Tower



6.0 DATA SUMMARY

The RPHP contends that gross beta concentrations, including Sr-90 concentrations, are rising. The DEP has found no evidence of this in any of the state or federal monitoring data reviewed. There are minimal discharges of Sr-90 in air (Figure 10). Concentrations are at or below the MDC (0.00015 pCi/m^3 historic average for sample locations around OCNGS). Any readings above the MDC are less than 1/10,000th of the allowable NRC discharge levels.

The RPHP also contends that there are higher Sr-90 concentrations in the deciduous teeth of children that live in Ocean and Monmouth counties in proximity to OCNGS, than in other New Jersey counties. However, since there were so few teeth obtained from Ocean and Monmouth counties (3), the RPHP states that no conclusions can be drawn currently. The primary route for incorporation of Sr-90 in children is through ingestion of milk. Since about 87% of the milk sold in New Jersey is produced outside of the state, a composite milk sample from Trenton, New Jersey is an adequate representation of milk consumed throughout New Jersey. The milk obtained from the composite sample from various markets in the Trenton area originate on farms throughout Eastern Pennsylvania, including the Lehigh Valley region. These EPA milk analyses show that Sr-90 levels in milk are declining since 1964, consistent with decay of Sr-90 from atmospheric weapons testing fallout.

7.0 SUMMARY OF BOUNDING CALCULATIONS FOR SR-90'S FATE IN THE ENVIRONMENT

Appendix B, titled "Bounding Calculation for Sr-90's Fate in the Environment", presents a conservative approach for determining whether or not it is plausible that the Sr-90 found in children's teeth could be from OCNGS. This calculation is based on modeling Sr-90 releases over the period of time that the Sr-90 would have been incorporated into the teeth that were analyzed by the RPHP (1980-1998). Conservative assumptions were used for deposition, atmospheric dispersion, the location of dairy cows, soil to plant transfer factors, feed to milk transfer factors, and infant feeding habits for the infant-milk pathway. Fetal uptake, ingestion of drinking water, and inhalation are also discussed. It is shown that the limiting pathway is the infant-milk pathway. By being overly conservative, one can determine the smallest release rate of Sr-90 from OCNGS that could possibly result in the concentrations of Sr-90 in the children's teeth analyzed by RPHP. If the recorded releases from OCNGS are below this calculated release rate, then it can be concluded that the Sr-90 found in children's teeth is not from OCNGS.

The infant-milk modeling assumes that there is a dairy farm at the location of highest deposition based on site-specific meteorological data from OCNGS. Once the Sr-90 deposits on the ground, it is assumed that 25% of it lands directly on grass that is consumed by the cows. The rest of the Sr-90 lands on the soil, where it is incorporated into the grass from root uptake. A conservative value is used for the soil to plant transfer factor. After the cows consume the grass, another conservative factor is applied, the feed to milk transfer factor, which provides the amount of Sr-90 available in the cow's milk.

Appendix B references work by Aarkrog [9] who demonstrated that the crowns of teeth are formed during the first year after birth and that Sr-90 concentrations in the crowns remain constant up through the time that the teeth are shed. This means that only the calcium in cow's milk consumed in the first year of life would be incorporated into the teeth.

The results show that in order for the teeth of children to contain 2 pCi of Sr-90 per gram of calcium (the approximate Sr-90 concentration observed in teeth in the RPHP study), the Sr-90 release rate from OCNGS would have to be about 0.38 Curies per year (Ci/y) from the stack. The actual average annual Sr-90 releases from OCNGS from 1972 through 1997 were reported to be 0.0035 Ci/y. Hence there is virtually no possibility that the Sr-90 observed in the teeth of children in the vicinity of OCNGS was due to Sr-90 emissions in the gaseous effluents of the plant.

8.0 SCIENTIFIC METHODOLOGY

Scientific methodology is a way of approaching and solving a problem or answering a question. Good scientific methodology attempts to minimize the influence of bias or prejudice. In any study it is necessary to scrutinize the methodology used when conclusions deviate from the general scientific consensus.

In planning a research study, good scientific principles require consideration of whether the study can be replicated and whether it has evaluated all of the possible explanations for what has been observed. All relevant data need to be considered, not just selective data, and the data needs to be valid and reliable. If sample analysis is required, the analytical laboratory performing the sample analyses should be certified.

The RPHP study did not establish control populations for the study nor consider all the counties near the Oyster Creek Nuclear Generating Station. The impacts of other risk factors were not considered such as genetic predisposition, parental chemical occupational exposures, and exposure to other potential carcinogens. Data that did not fit the RPHP's conclusions, such as data collected in certain geographical areas or certain time periods, were not presented. Interpretation of existing data did not appear to be objective.

The laboratory used by the RPHP to analyze samples for Sr-90 was not certified for Sr-90 analysis. No information was provided regarding inter-laboratory comparison of results or validity and reproducibility of duplicates and spikes. No chemical yield information was provided for the precipitation step of sample analysis. At least one data point, 1.05 picoCuries per gram (pCi/g), is within the 2-sigma confidence interval (1.4 pCi/g) of the background data.

Additionally, samples and backgrounds were counted for different times. Stability of the background count rate for different count times is not addressed. There is also no indication that the authors have considered radium-226 as a confounder in counting data. Radium-226 is found throughout groundwater in Ocean and Monmouth Counties and also has chemical properties similar to calcium.

A problem unique to radiochemical analysis is that measuring a radionuclide requires counting random radioactive emissions from a sample. The uncertainty associated with this counting provides information on what the measurement might be if the same sample were counted again under identical conditions. Since the half-life of Sr-90 is approximately 30 years, it is possible to estimate, from a single measurement, the spread or scatter of a measured number of counts about a mean value. This determination is usually called the "counting uncertainty." This takes into consideration only the random scatter about the mean from the radioactive decay process itself. To presume that this is the only source of random fluctuation in the overall measurement or counting process is erroneous. Other potential sources include random timing uncertainties, variations in the sample preparation, standards preparation, positioning of the sample at the detector, etc. The list is nearly endless.[10]

None of the individual tooth results of pCi of Sr-90 per gram of calcium are reported in the RPHP study. Only averages are compared. In order for the data to be appropriately analyzed, each data point with its associated 2-sigma uncertainty should be presented. A 2-sigma counting uncertainty indicates that approximately 95% of the time, a recount of the same sample would give a value somewhere between the reported value minus the counting uncertainty and the reported value plus the counting uncertainty. Appendix 1 of the RPHP report states that the overall uncertainty of one sigma is $\pm$ 0.7 pCi Sr-90 per gram of calcium. It is not clear if this is just the counting uncertainty or the total uncertainty. In any case, each result should have its own uncertainty associated with it. "A reported value without an accompanying uncertainty statement is, for nearly all purposes, worthless. The value is rendered useless because it cannot be put to use with any confidence."[11] In this case, however, not only is the uncertainty missing, but the actual data are not even presented. If the data were presented with their associated uncertainty, an independent statistical analysis could be done to determine if there really was a difference between the two populations, for example the teeth of children with leukemia versus teeth of children with all other cancers. Without the data, this report is of no scientific value and certainly cannot be used to justify further funding.

Footnotes

1. "*Understanding Patterns and Trends of Radioactive Sr-90 in Baby Teeth of New Jersey Children with Cancer: A Report to the New Jersey State Department of Health and Human Services*", Radiation and Public Health Project, November 2004.

2. U.S. Nuclear Regulatory Commission Backgrounder, "*Radiation Protection and the Tooth Fairy Issue*". Visit the NRC Internet website at: http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/tooth-fairy.html for additional information.

3. U.S. Nuclear Regulatory Commission (NRC), 1991. NUREG/CR-2907, Vol.14 "*Radioactive Materials Released from Nuclear Power Plants, Annual Report, 1993.*"

4. National Cancer Institute (NCI), 1990. *Cancer in Populations Living Near Nuclear Facilities*. Bethesda, Maryland.

5. University of Pittsburgh, "*Mortality among Residents of the Three Mile Island Accident Area: 1979-1992*", Environmental Health Perspectives, Volume 108, Number 6, June 2000.

6. American Cancer Society (ACS), 2001c. "*1998 Facts & Figures. Environmental Cancer Risks.*" Accessed online: http://www.cancer.org/statistics/cff98/enviromental.html .

7. U.S. Nuclear Regulatory Commission Regulatory Guide 1.21, "*Measuring, Evaluating, and Reporting Radioactivity in Solid Wastes and Releases of Radioactive Materials in Liquid and Gaseous Effluents from Light-Water-Cooled Nuclear Power Plants*" (6/1974)

8. GPU Nuclear Corporation/Amergen Energy Company, LLC, "*Annual and Semi-Annual Effluent Release Reports*", 1987 through 2004.

9. Aarkrog, A, " Prediction Models for Sr-90 in Shed Deciduous Teeth and Infant Bone," Health Physics, Vol 21 (December), pp 803-809, 1971.

10. US Environmental Protection Agency, August 1980, EPA 520/1-80-012. Upgrading Environmental Radiation Data. "Reporting of Environmental Radiation Measurements Data". p.6-14.

11. US Environmental Protection Agency, August 1980, EPA 520/1-80-012. Upgrading Environmental Radiation Data. "Reporting of Environmental Radiation Measurements Data". p.6-8.

Appendix A

Letter from the Commission on Radiation Protection
Ms. Julie Timmons, M.D., Chairman
Commission on Radiation Protection

State of New Jersey
Department of Environmental Protection
New Jersey Commission on Radiation Protection
Department of Environmental Protection
P.O. Box 415
Trenton, NJ 08625-0415

James E. McGreevey
Governor

Bradley M. Campbell
Commissioner

February 18, 2004

The Honorable James E. McGreevey
Governor
State of New Jersey
State House
P.O. Box 1
Trenton, NJ 08625-0001

RE: Response to your request for review of the Radioactive Strontium-90 in Baby Teeth Project

Dear Governor McGreevey:

The New Jersey Commission on Radiation Protection (the Commission) has significant concerns about the scientific validity of the proposal, "Radioactive Strontium-90 in Baby Teeth of New Jersey Children and the Link with Cancer: A Special Report", also known as the Tooth Fairy Project (the Project). The investigators have applied for and were granted funding by the New Jersey Legislature. The premise of the investigators is that currently operating nuclear power plants in New Jersey are causing unnecessary radiation exposure to the citizens of this state, particularly children and/or their pregnant mothers, resulting in an increase in childhood cancers. The Project proposes to evaluate children's radiation exposure by measuring Strontium-90 (Sr-90) levels in extruded baby teeth.

The members of the Commission have extensive knowledge in the sciences, including physics, radiology, radiation biology, medicine, and epidemiology. Commission members have been involved in the epidemiologic study of childhood cancer, and have served on advisory panels on radiation and radiation protection. Some members work for the New Jersey Department of Environmental Protection, Radiation Protection and Release Prevention element. The Commission is well qualified to evaluate the scientific merits and methods of the Project.

The Tooth Fairy Project has several faulty premises or hypotheses.

- New Jersey's nuclear power plants are a significant source of Sr-90 and release significant amounts of Sr-90 into the environment.
Most Sr-90 – approximately 99.6% - comes from above-ground atomic weapons testing that occurred in the late 1940's and continued through 1968, when an above-ground test ban treaty was enacted. Strontium that was deposited in the ground as the result of weapons testing

remains there and can be ingested even today. The remaining 0.4% of Sr-90 is attributed to nuclear power plants.

Nuclear power plants routinely monitor radioactivity with radiation monitoring equipment both inside and outside the plant. In addition, the State of New Jersey has an environmental monitoring program that was started in 1969 to measure environmental radioactivity. Approximately 1400 samples are collected yearly around the nuclear generating plants of Oyster Creek, Salem 1 and 2, and Hope Creek. These samples are compared with background samples taken from the Brendan T. Byrne State Forest, an area far removed from any nuclear power plants. No increase in radioactivity has been found. Sr-90 is a beta radiation emitter with a long physical half-life. If one assumes the gross beta radiation levels found in the environment are attributable to only Sr-90, the resultant dose would be well below the Nuclear Regulatory Commission's limit of 20 millirad per year. Levels of Sr-90 in air have been less than the minimum detectable concentration.

Organizations such as the Atomic Energy Commission, the National Council on Radiation Protection and Measurements, the United Nations Committee on the Effects of Atomic Radiation, and the International Commission on Radiological Protection have studied the public health risks of radioactive materials in the environment, including Sr-90. No credible scientific studies have shown environmental Sr-90 to pose a current health risk, whether due to weapons testing or from nuclear power plants. Sr-90 is a small component of nuclear reactor releases. Populations living near nuclear power plants receive an effective dose of less than 1 mrem annually from all aggregated radioisotopes released by nuclear power plants, including but not limited to Sr-90. To put this in perspective, the average person in the United States receives approximately 300 mrem effective dose annually from natural sources including radon, cosmic, terrestrial and internally deposited radionuclides.

- Proximity to nuclear power plants during pregnancy and/or infancy correlates with childhood cancer incidence.
The National Cancer Institute conducted a case control study, published in the *Journal of the American Medical Association* on March 20, 1991, showing no increased risk of death from cancer for people living in 107 US counties containing or adjacent to 62 nuclear power facilities. Included were 52 commercial nuclear facilities, 9 Department of Energy research and weapons plants, and 1 commercial fuel reprocessing plant. The study found that the risk of childhood leukemia in the counties studied was slightly greater before start-up of the nuclear facilities than after they were in operation.

- Sr-90 released by New Jersey's nuclear power plants is ingested by nearby cows and is excreted in the cows' milk. This milk is ingested by pregnant women and young children and is deposited in children's teeth.
There has been no documentation of significant Sr-90 release from nuclear power plants in New Jersey. In addition, very little of the milk sold in New Jersey comes from New Jersey cows. Data from the Department of Agriculture indicates that only 12.6% of the milk consumed in New Jersey comes from New Jersey dairies. There are no dairy farms within a 10-mile radius of Oyster Creek; the closest dairy farms are approximately 30 miles away.

- Methodology of determination of Sr-90 in teeth:
The investigators note in their report that the analytic method used to measure Sr-90 concentrations in teeth was changed in June 2000. The new method was used for analysis of the baby teeth collected from New Jersey residents. They note that the results of the new analytic method differ from those of the previous method, and thus should not be compared directly. This raises significant concerns about the validity and consistency of radiation levels measured and data processing. The Project reports results on a contemporaneous inter-laboratory comparison of Sr-90 measurements between two facilities based on 10 teeth. This is hardly an adequate sample to validate comparability of data; additionally, only summary information is provided, precluding a rigorous statistical comparison.

Methods of measuring beta radiation in teeth include the tooth-beta counter (a gas-flow Geiger-Muller detector used on in vivo incisor front teeth), radiochemical techniques, and electron paramagnetic resonance spectroscopy. A recent study published in the journal *Health Physics* in October 2003, found the tooth-beta counter to be the most reliable method for reconstruction of Sr-90 intake, and that accuracy requires that a significant number of measurements be performed on teeth of the same type (e.g., incisors or molars). The Tooth Fairy Project employs a radiochemical technique and uses primary teeth from a variety of positions in the mouth.

The Project compares Sr-90 levels in teeth obtained from New Jersey residents to levels in teeth from other states. However, the methodology of Sr-90 determination of teeth from other states is not specified. It is highly likely that data collected from other states was analyzed using an older methodology, and that the results are not comparable.

- Tooth collection, sampling, and statistical validity:
The Report makes statements about the geographic patterns of Sr-90 distribution in New Jersey teeth by county. However, disaggregated data are not provided nor are estimates of the reliability of measurements, making it impossible to conduct a thorough evaluation of the patterns. This is of particular concern because over 60% of the tooth samples were from one county. The data from other counties is likely to be unreliable due to small sample sizes. Additionally, only averages of Sr-90 levels are provided, without ranges and standard errors, precluding statistical hypothesis testing. Given the variability of the measurement methods and other factors that may influence the concentration of Sr-90 in teeth, the reported geographic patterns are not valid or interpretable, nor are the temporal trend analyses.

There is a lack of details on the characteristics of the respondents, such as demographic or socioeconomic profiles. Information on maternal history that could affect maternal Sr-90 levels, such as in which states the mother has resided or detailed nutritional history, is not available. In addition, there are systematic errors in the Project. These include volunteer bias and possible confounding bias. The Project does not have adequate "controls", such as large numbers of primary teeth collected from children born and raised in areas without nuclear power plants.

- How Sr-90 is deposited in primary teeth:
Strontium is a calcium analog and can enter a child's teeth at different times and from different sources. The body of the child's mother can contain Sr-90 accumulated prior to or during

pregnancy, which can pass through the placenta. Placental transfer of strontium varies during pregnancy. Additionally, the amount of strontium incorporated in a primary tooth from prenatal transfer is related to the rate of calcification of the tooth. "Baby teeth" or primary teeth start to calcify at approximately 12-13 weeks of fetal life. The degree of primary tooth calcification at birth varies: central incisors have 5/6 of their enamel formed by the time of birth, canines 1/3, and maxillary second molars between 1/4 and 1/5.

Enamel formation continues after birth. The infant may ingest Sr-90 in breast milk and the young child may ingest it in cow's milk and other food products. An individual child's primary incisors could have substantially more or less Sr-90 than his canines or molars. However, the Tooth Fairy Project uses all types of primary teeth for Sr-90 determination. Baby teeth are tested individually using a scintillation counter, which measures picocuries of Sr-90 per gram calcium, which is later extrapolated to levels at birth, using a Sr-90 half-life of 28.7 years. This extrapolation disregards Sr-90 ingested post-partum.

Conclusion:
The Commission is of the opinion that "Radioactive Strontium-90 in Baby Teeth of New Jersey Children and the Link with Cancer: A Special Report" is a flawed report, with substantial errors in methodology and invalid statistics. As a result, any information gathered through this project would not stand up to the scrutiny of the scientific community. There is also no evidence to support the allegation that the State of New Jersey has a problem with release of Sr-90 into the environment from nuclear generating plants: more than 30 years of environmental monitoring data refute this. Other state governments have been approached to support the Tooth Fairy Project. The Departments of Health of Minnesota, Pennsylvania, and Michigan have refuted the Project's allegations of public radiation burden due to Sr-90 release from nuclear power plants.

The Commission offers its assistance in evaluating the results and conclusions of any more reports which are generated by the Tooth Fairy Project, but recommends against any further support for the researchers unless they demonstrate that they are using current peer-reviewed scientific methods.

Sincerely yours,

Julie U. Timins MD.

Julie Timins, M.D., Chairman
Commission on Radiation Protection

Appendix B

Summary of Bounding Calculation for Sr-90's Fate in the Environment

John Mauro, Ph.D., CHP, Commission Member
Jenny Goodman, Research Scientist, NJDEP

A series of calculations are performed that evaluate the plausibility of the RPHP hypothesis that children in the vicinity of Oyster Creek Generating Station have elevated levels of Sr-90 in their teeth, and that the elevated levels, if they in fact exist, are due to Sr-90 emissions from Oyster Creek.

The following presents an example scoping calculation of how such an analysis could be performed. The scoping calculation establishes a generic bounding relationship between the concentration of Sr-90 in teeth in children residing at the closest offsite location of Oyster Creek and the Sr-90 release rate from the facility, expressed in units of pCi of Sr-90 per gram of calcium in teeth per Ci per year of Sr-90 chronically released in the gaseous effluents of a power plant. The product of this value with the actual average annual release rate of Sr-90 in the gaseous effluent of Oyster Creek will yield an upper bound estimate of the concentration of Sr-90 in the teeth of children due to the Sr-90 emissions from the plant. The relationship is considered bounding because the analysis assumes that a child obtains all of his or her milk from a cow located downwind at the closest location to the power plant. In addition, the analysis employs a number of environmental transport factors, which tend to result in an overestimate of the possible exposures to children via this pathway. The scoping calculation can be used to quickly determine if the concentration of Sr-90 actually observed in children's teeth could possibly have been due to the emissions of Sr-90 from Oyster Creek[1], or whether it is more likely that the Sr-90 observed in teeth is due to other sources, namely residual levels of Sr-90 in the environment due to weapons testing fallout.

This scoping calculation is provided as a guide to RPHP and Mr. Mangano. A more definitive analysis applicable specifically to Oyster Creek would employ the actual location of dairy cows in the vicinity of the plant, the actual forage practices used at the dairy, and site-specific environmental transport factors. These parameters are available in reports prepared by the utility and filed with the Nuclear Regulatory Commission.

Question 1: Is it plausible that the shed deciduous teeth of children and infants evaluated in the RPHP study contain Sr-90 at the reported concentrations?

Mr. Mangano reported that the Sr-90 concentrations in the teeth of children were found to range from 1.05 to 4.2 pCi/g of Sr-90 per gram of calcium depending on type of teeth (molars versus incisors) and birth year (ranging from 1980 to 1998), with an overall average of 2.27 (Table 3 of RPHP report).

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[1] The basic methodology described in this report can be used for any nuclear power plant.

Aarkrog (1971)[2] demonstrates that the concentration of Sr-90 present in the crowns of shed deciduous teeth, expressed in units of pCi of Sr-90 per gram of calcium, is indicative of the Sr-90 concentration in the bones of those children at the age of 1-year old. The implication is that the crowns of teeth are formed during the first year after birth and that the Sr-90 concentrations in the crowns remain constant up through the time that the teeth are shed at around the age of six years old. On this basis, we can assume that all of the Sr-90 and all of the calcium in shed teeth originate from the Sr-90 and calcium ingested during the first year after birth. Hence, in order for the shed teeth analyzed in the RPHP study to contain about 1 to 4 pCi of Sr-90 per gram of calcium, the infants' diet during the first year after birth must also have contained about 1 to 4 pCi of Sr-90 per gram of calcium. The question is, is this plausible?

By far, the principal source of calcium and Sr-90 in an infants' diet is milk. Therefore, it is appropriate to ask: Is it plausible that the children involved in this study ingested milk that contained 1 to 4 pCi of Sr-90 per gram of calcium during their first year after birth? It is appropriate to point out here that the American Academy of Pediatrics recommends no cow's milk for the first year of life. For this calculation the conservative assumption is made that breast milk contains the same amount of Sr-90 as cow's milk. This assumption is also conservative because an estimated 50% of children in the United States are fed infant formula. It is unlikely that the cow's milk used to manufacture the formula (80% of formula is manufactured from cow's milk) was derived from milk obtained at a dairy located at the site boundary downwind from Oyster Creek.

Figure 3 of the Aarkrog (1971) paper shows that the Sr-90 concentration measured in deciduous teeth crowns from children in Denmark was essentially 0 pCi of Sr-90 per gram of calcium in 1950, climbed steadily to a peak of about 7 pCi of Sr-90 per gram of calcium in 1963 (i.e., the years of above ground nuclear tests), and declined steadily from 1963 to 1968 to a low value of 2 pCi of Sr-90 per gram of calcium.

Figure 9-23 of Eisenbud and Gesell (1997)[3] reveals that the average annual Sr-90 concentration in milk samples collected in New York City ranged from essentially zero in 1954, rose to a peak of about 25 in 1963, and then steadily declined to about 2 pCi/g Sr-90 per gram calcium in 1982. The report also indicates that, in 1982, the Sr-90 concentration in milk was gradually declining at a rate of 2.4% per year due to radioactive decay and an additional 8% per year due to reduced availability of Sr-90 from soil.

Attachment B-1 to this appendix presents a tabulation of the Sr-90 concentration in milk samples collected in New Jersey from 1960 to 2004. The concentrations are expressed in

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[2] Aarkrog, A, " Prediction Models for Sr-90 in Shed Deciduous Teeth and Infant Bone," Health Physics, Vol 21 (December), pp 803-809, 1971.

[3] Eisenbud, M and T. Gesell, "Environmental Radioactivity from Natural, Industrial, and Military Sources," Fourth Edition, Academic press, 1997.

terms of pCi/L of whole milk. Since milk contains about 1.1 grams of calcium per liter[4], the Sr-90 concentrations in milk (expressed in units of pCi/L) can be divided by 1.1 to yield Sr-90 concentrations expressed in units of pCi of Sr-90 per gram of calcium in whole milk. Using the values in Attachment B-1 for the bounding years of the study, the Sr-90 concentrations in milk are as follows: 4.2 pCi of Sr-90 per gram of calcium in milk for 1980 and 1.02 pCi of Sr-90 per gram of calcium in milk for 1998. These Sr-90 values reported in the literature are virtually identical to the values presented in Table 3 of the RPHP report. As a result, it is certainly plausible that the Sr-90 concentration in the teeth of children collected in the RPHP study were on the order of 1 to 4 pCi of Sr-90 per gram calcium. However, the data indicate that the Sr-90 observed in teeth and milk was likely due to weapons testing fallout.

Question 2: Is it plausible that the Sr-90 observed in the teeth of children in the vicinity of the Oyster Creek nuclear power plant is due to Sr-90 emissions from the plant?

Though the above discussion would seem to indicate that the levels of Sr-90 in teeth observed in the RPHP study are likely due to Sr-90 from global fallout, it is instructive to ask the question whether some or all of the Sr-90 in teeth obtained from children in the vicinity of the Oyster Creek nuclear power plant could have been due to Sr-90 emissions from the plant.

One way to answer this question is to derive a generic relationship between the release rate of Sr-90 in the gaseous effluent of a commercial nuclear power plant and the concentration of Sr-90 in the teeth of children residing in the vicinity of the plant. Such a relationship, which can be referred to as a generic Sr-90 concentration factor, can be expressed in units of pCi of Sr-90 per gram of calcium in teeth per Ci per year of Sr-90 released from a given nuclear power plant. Then, if one can determine the actual release rate of Sr-90 from a given nuclear power plant, one can place an upper bound on the concentration of Sr-90 that may be expected in children's teeth due to those releases.

The generic relationship is based on the assumption that (1) the majority of the calcium and Sr-90 ingested by infants and children comes from milk, and (2) the vast majority of Sr-90 in milk is due to Sr-90 in the feed and pasture ingested by cows. The U.S. Nuclear Regulatory Commission (Table E-1 of NRC 1977)[5] recommends a feed to milk transfer factor for Sr-90 of 8.0E-4 pCi of Sr-90 per liter of milk per pCi of Sr-90 ingested per day by milk cows. This value was determined by empirical measurements of the Sr-90 concentration in milk and the amount of Sr-90 ingested per day by milk cows. The values reported in Table 2 of Hoffman (1982)[6] range from 2E-4 to 8E-2 pCi/L of Sr-90 in

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4 According to USDA National Nutrient Data Base for Standard Reference for calcium, 1 cup of whole milk (i.e., 8 ounces) contains 276 mg of calcium.

5 U.S. Nuclear Regulatory Commission, "Regulatory Guide 1.109 - Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR 50, Appendix I," Revision 1, October 1977.

6 Hoffman, F.O., Gardner, R.H., and Eckerman, K.F. 1982. *Variability in Dose Estimates Associated with the Food Chain Transport and Ingestion of Selected Radionuclides*. NUREG/CR-2612.

milk per pCi of Sr-90 ingested per day by milk cows, with a geometric mean 1.2E-3. In order to ensure that we will not underestimate the transfer factor, the geometric mean value cited by Hoffman 1982 is used here. Since milk cows on pasture ingest about 50 kg of fresh forage per day (NRC, 1977 page 38), the forage or grass would need to contain about 16.6 pCi of Sr-90 per kg of fresh grass in order for milk to contain 1 pCi/L of Sr-90.

The grass can become contaminated by Sr-90 by two methods: (1) root uptake from Sr-90 in soil and (2) direct deposition of Sr-90 onto grass (Figure B-1). The following presents the methods used to calculate the generic Sr-90 concentration factor.

<u>Generic Root Uptake Concentration Factor</u>:

Table E-1 of NRC 1977 recommends a soil to vegetable transfer factor of 0.017 pCi of Sr-90 per kg of fresh vegetables (including grass) per pCi of Sr-90 per kg of dry soil. This means that, if there is 1 pCi of Sr-90 in a kg of soil, each kg of fresh grass growing in that soil can be expected to contain 0.017 pCi of Sr-90. Hoffman (1982) presents a summary of the literature on the soil to plant transfer factors for Sr-90 in pasture. The values for pasture range from a minimum of 0.06 to a maximum of 46, with a mean of 1.4 pCi/kg of dry weight pasture per pCi/kg dry weight soil. Using a wet weight to dry weight ratio of 5.5 (see Table 5.16 Peterson[7]), this translates to a mean of 0.25 and a range of 0.01 to 8.2. Using the higher of the recommended values for the soil-to-grass transfer factor (i.e., Hoffman's

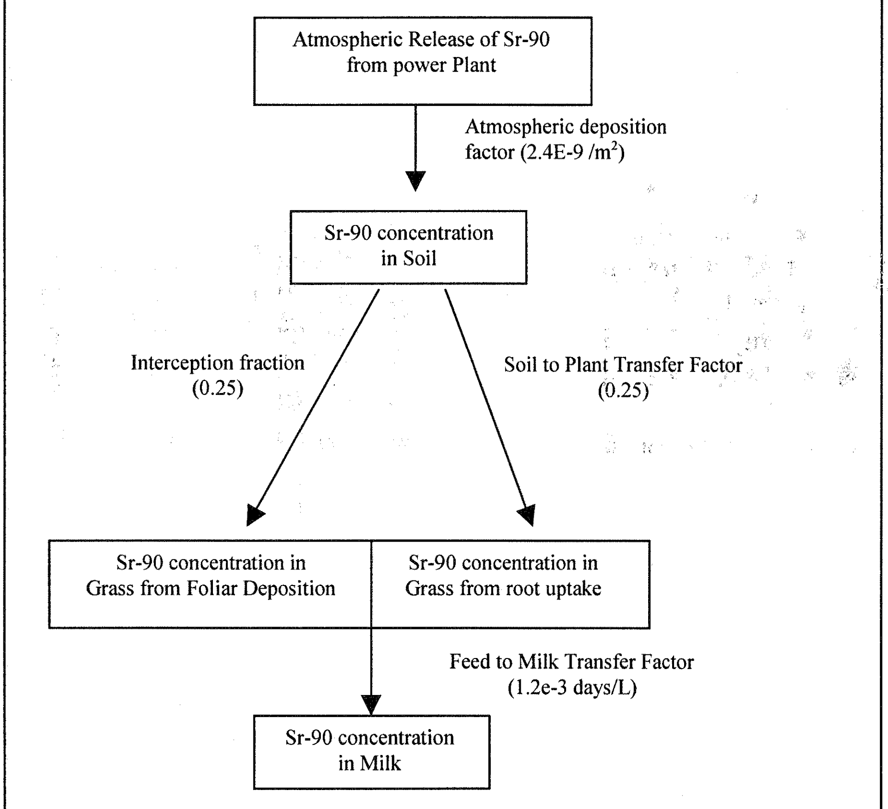

Figure B-1. Grass Root Uptake and Direct Foliar Deposition of Sr-90

[7] Peterson, H.T. 1982. "Terrestrial and Aquatic Food Chain Pathways." In: *Radiological Assessment*. Till, J.E. and Meyer, H.R., eds. NUREG/CR-3332. Washington, DC: U.S. Nuclear Regulatory Commission.

mean of 0.25 rather than the NRC's value of 0.017), the soil would need to contain 66.5 pCi of Sr-90 per kg dry weight of soil in order for fresh grass to contain 16.6 pCi of Sr-90 per kg. The following equation can be used to predict the radionuclide concentration in soil at any location in the vicinity of a nuclear power plant due the routine airborne emissions of radionuclides from the plant.

$$C_s = R \times D/Q \times T \times 10^{12} / 240$$

where:

C_s = Sr-90 concentration in soil at a given location (pCi/kg dry weight)
R = Average annual release rate of Sr-90 from the plant in its gaseous effluents (Ci/yr)
D/Q = Atmospheric deposition factor at a given location in the vicinity of the plant ($1/m^2$)
T = Time period from the startup date of plant operations to the year of interest (years)
10^{12} = unit conversion (pCi/Ci)
240 = amount of contaminated soil per square meter (kg of soil per square meter)

A few of the terms in this equation require some explanation. The term D/Q is the atmospheric deposition factor for the offsite location in the vicinity of Oyster Creek with the greatest potential for radionuclide deposition due to elevated radionuclide releases from the plant stack. For Oyster Creek, this location is 996 meters southeast of the plant and the value for D/Q is 2.4E-9 per square meter.[8] This parameter is derived from meteorological data collected from the plant's meteorological tower, along with mathematical models recommended by the Nuclear Regulatory Commission for use in deriving offsite exposures from airborne emissions from nuclear power plants. Note that the product of the radionuclide release rate, R, expressed in units of Ci/yr, along with the deposition factor, (D/Q), expressed in units of $1/m^2$, yields the rate at which radionuclides released from the plant are depositing on the ground at a given location, expressed in units of Ci/year per square meter. The total amount of a given radionuclide deposited at that location over some time period, expressed in units of pCi/m^2, is obtained by multiplying the deposition rate by the time period over which deposition occurs, which is assumed to be 20 years (the midpoint for a typical 40 years of plant operations). This is a conservative assumption because it is widely recognized that the radionuclides in soil often erode away by wind and rain and do not continually accumulate indefinitely.

Finally, the total amount of Sr-90 deposited on soil at a given location, expressed in units of pCi/m^2, is converted to the Sr-90 concentration in soil at that location, expressed in units of pCi/kg, by dividing by 240 kg of soil per square meter. This value is based on the assumption that, as the Sr-90 deposits onto soil, it is uniformly mixed into the soil down to the root zone of pasture, which is assumed to be 15 cm (Table E-15 of NRC 1977).

Using these assumptions, the normalized Sr-90 concentration in soil, grass, and milk, and the generic root uptake concentration factor, are as follows for elevated releases:

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8 Information provided by the New Jersey Department of Environmental Protection (NJDEP)

•200 pCi of Sr-90/kg of soil per Ci/yr of Sr-90 released from the plant stack.
•50 pCi/kg of grass per Ci/yr of Sr-90 released from the plant
•3 pCi of Sr-90/L of milk per Ci/yr of Sr-90 released from the plant
•2.7 pCi of Sr-90 per gram of calcium per Ci/yr of Sr-90 released from the plant

Generic Direct Foliar Deposition Concentration Factor:

Fresh forage can also become contaminated by direct foliar deposition of Sr-90 onto grass. The following equation is used to derive the concentration of Sr-90 on grass due to direct foliar deposition of Sr-90 released in the gaseous effluent of a nearby nuclear power plant.

$C_f = R \text{ x } D/Q \text{ x } f \text{ x } 10^{12} /(Yv \text{ x } \lambda_e \text{ x } 365)$

Where:

C_f = Sr-90 concentration in grass from direct deposition (pCi/kg)
f = fraction of deposited Sr-90 that deposits directly on grass
Yv = grass yield (kg/m^2)
λ_e = the effective half life of Sr-90 on grass (days)
10^{12} = unit conversion (pCi/Ci)
365 = number of days per year

The terms R, D/Q are used in this equation in the same manner as described above. The term f is the fraction of the deposited Sr-90 that deposits directly onto grass. Table E-15 of NRC 1977 recommends a value of 0.25. This means that 25% of the deposited radionuclides is assumed to land directly onto grass and the other 75% deposits directly onto soil. The term Yv is the amount of grass per square meter. Table E-15 of NRC 1977 recommends a value of 0.7 kg/m^2. The term λ_e is the retention coefficient for Sr-90 on grass. Table E-15 of NRC 1977 recommends a value of 0.0495 per day, which corresponds to a 14 day half life. This means that the Sr-90 that deposits onto grass has an effective half-life of 14 days due to weathering from wind and rain.

Using this equation, the concentration of Sr-90 on grass downwind from the plant at the location with the highest potential for contamination due to airborne radionuclides released from the plant stack is 47 pCi/kg per Ci per year of Sr-90 released. The Sr-90 concentration in milk would be 2.8 pCi/L per Ci per year of Sr-90 released from the plant stack. This value translate to 2.6 pCi of Sr-90/g of calcium per Ci/yr of Sr-90 released from the plant stack.

Total Generic Sr-90 Concentration Factor:

The sum of the generic root uptake concentration factor (2.7) and the generic direct deposition concentration factor (2.6) yields an overall generic concentration factor of 5.3 pCi/gram calcium per Ci/yr of Sr-90 released from the plant stack at Oyster Creek. The implications of this calculation are that, in order for the teeth of children to contain 2 pCi of Sr-90 per gram of calcium (i.e., the approximate Sr-90 concentration observed in teeth in the RPHP study), the Sr-90 release rate would have to be about 0.38 Ci/y for elevated releases. The actual average annual Sr-90 releases in the gaseous effluent of Oyster Creek from 1972 through 1997 were reported to be 3.5E-3 Ci/yr (based on data provided by NJDEP). Hence, based on this generic scoping analysis, there is virtually no possibility that the Sr-90 observed in the teeth of children in the vicinity of Oyster Creek was due to Sr-90 emissions in the gaseous effluents of the plant.

Fetal Exposures to Sr-90

In the Introduction/Background section of the November 10, 2004 report prepared by the Radiation and Public Health Project (RPHP), concern is expressed that Sr-90 may be "particularly toxic to the fetus, infant, and young child." RPHP also states that virtually all Sr-90 uptake in the teeth occurs during pregnancy/early infancy. It was demonstrated above that the Sr-90 observed in deciduous teeth of children, as reported by the RPHP, likely originated from weapons testing fallout and could not be from airborne releases from the Oyster Creek nuclear power plant unless (1) the average annual airborne releases from the plant were about 100 times greater than reported by the utility or the releases were from ground level as opposed to elevated sources, (2) cows were located at the offsite location with the highest potential for exposure (i.e., 966 meters SE of the plant), and (3) infants obtained all their milk (or the nursing mother obtained all her calcium) from the milk of cows at that location. In this section of the report, the possibility that a developing fetus could accumulate Sr-90 at levels greater than those estimated for infants and children is explored. It will be demonstrated that the concentration of Sr-90, expressed in terms of pCi of Sr-90 per gram of calcium (referred to as the "strontium unit"), in a developing fetus under hypothetical worst case conditions would be several times lower than the levels derived for infants and children above.

There are two reasons why the concentration of Sr-90 in a developing fetus would be several fold lower than in infants and children. First, in the process of transport across the placenta, the Sr-90 is discriminated against relative to calcium, resulting in a lower strontium unit in the fetus as compared to the diet of the mother, and, second, the source of Sr-90 in the diet of an adult includes food sources other than milk, thereby reducing the amount of Sr-90 ingested by an adult, as compared to that ingested by an infant or child. These two factors have the effect of reducing the strontium unit in a developing fetus as compared to an infant. A brief overview is provided of the metabolism of Sr-90, followed by a description of the two factors that are responsible for the lower strontium unit in the developing fetus as compared to infants and children.

Metabolism of Sr-90

NCRP Report No. 110[9] provides a comprehensive summary of the literature addressing the metabolism of Sr-90 in humans. The key point is that Sr-90, whether inhaled or ingested, will be metabolized as if it were calcium. This occurs because of the chemical similarity between strontium and calcium. Because of biochemical similarities, the

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[9] NCRP Report No. 110. "Some Aspects of Strontium Radiobiology," National Council on Radiation Protection and Measurements, August 31, 1991.

concentration of Sr-90 in various food products and in the human body is often expressed in terms of pCi of Sr-90 per gram of calcium, which is referred to as the strontium unit. This is a convenient metric because if the strontium unit in a person's diet is known, it can be assumed that the person will eventually have a similar value for the strontium unit in the various tissues of his or her body, such as bone and teeth. As discussed in previous sections, the food item that has the highest concentration of Sr-90 is milk, and if milk is the major source of calcium in a person's diet, it can be concluded that the observed ratio in the tissues of a person's body will be similar to that in milk.

In previous sections of this report, it was demonstrated that the strontium unit in milk sampled from several locations in the northern hemisphere, including pooled samples of milk collected in Trenton, is the same as in the teeth analyzed in the RPHP study. The implications are that the calcium and Sr-90 in the deciduous teeth analyzed in the RPHP study came from the ingestion of milk.

Discrimination of Sr-90 at the Placenta

It is assumed for this exercise that a pregnant woman ingested the same milk that was assumed to be ingested by the hypothetical infant that was modeled in the previous sections of this report, and that this milk was the only source of Sr-90 and calcium in the woman's diet. In reality, the woman would likely have other food items in her diet that would lower her ingestion rate of Sr-90. Hence, such an assumption can be considered "worst case" because it maximizes the amount of Sr-90 ingested by the woman. Under these circumstances, the strontium unit in the developing fetus would be expected to be about a factor of 0.6 times lower than in the milk because of discrimination against Sr-90 relative to calcium by the placenta.[10] Numerous other studies have confirmed this discrimination factor.[11] In other words, the differences in the biochemistry of strontium and calcium are such that the placenta is relatively more efficient at transferring calcium to the developing fetus than strontium from the mother's diet. As a result, the concentration of Sr-90 in the various tissues of a developing fetus, expressed in units of pCi Sr-90 per gram of calcium, would be expected to be about 60% of that in dietary milk and of that in the bone and teeth of the infant modeled in previous sections of this report.

Dietary Intake of Calcium and Sr-90 in Adults

In reality, the source of calcium in the diet of an adult is not entirely from milk. The Ohio State University Extension Fact Sheet (http://ohioline.osu.edu/hyg-fact/5000/5557.htms) states that a typical American diet consists of:

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[10] T.P. Fell, J.D. Harrison, and R.W. Leggett, "A Model for the Transfer of Calcium and Strontium to the Fetus," Radiation Protection Dosimetry 79:311-315 (1998).

[11] NCRP Report No. 128, "Radionuclide Exposure of the Embryo/Fetus," National Council on Radiation Protection and Measurements, September 25, 1998

Food Item	Percent Intake of Calcium
Dairy Products	74.5%
Meat, Poultry, Fish	3.4%
Legumes, Nuts, Soy	3.7%
Vegetables	6.2%
Grain Products	4.4%
Other Foods	5.2%

In addition, about 60% of the dairy foods ingested by an adult consists of milk. The other 40% consists of cheese, ice cream, yogurt, and other processed foods[12] that would probably not come from a hypothetical cow located in the vicinity of Oyster Creek. Accordingly, the strontium unit in an adult that lives in the vicinity of Oyster Creek and obtains all her milk from a local dairy would be about 44% (i.e., 0.74 x 0.6) of that in an infant that obtains all its milk from a local cow. Hence, between placental discrimination and dietary factors, the strontium unit in the tissues of the developing fetus would be about 27% (i.e., 0.6 x 0.74 x 0.6) of that in the hypothetical infant modeled in other sections of this report. This confirms that the most limiting pathway is the infant-milk pathway, which was modeled in the previous section.

Drinking Water Pathway

The RPHP study examines their results in the context of the source of drinking water. Although their report states that no conclusions can be drawn regarding which source of drinking water, either private or municipal, has higher concentrations of Sr-90, an investigation into the possibility of Sr-90 in drinking water is outlined below.

Starting with the conservative assumptions used in the infant-milk pathway analysis, namely the normalized value for the amount of Sr-90 deposited on the soil, it is shown through modeling, that a negligible amount of Sr-90 would be available in the drinking water. In the areas surrounding Oyster Creek there are both public and private drinking water sources. The majority of the public water is screened in the deep aquifer, which is located under a confining clay layer. Any Sr-90 would be stopped by this layer. There are many private wells, however, that are screened in the water table aquifer which is relatively shallow (approximately ten feet below the surface).

The RESRAD computer code (a standard residual radioactive materials model developed by the Department of Energy), was used to model the amount of Sr-90 that would leach into the shallow water table aquifer. The area of maximum deposition (as described in the infant-milk pathway analysis) was used as the source term. Using site-specific parameters for depth of well (50 feet below water table), unsaturated zone (9.5 feet), depth of contaminated layer (6 inches), and a conservative value for the distribution coefficient (a measure of the mobility of Sr-90 through soil), the results show that there would be no Sr-90 in drinking water. The actual amount was calculated to be 4.25E-10 pCi/L and would not be present for over 100 years from now.

12 USDA/Economic Research Service Web site. Last update December 21, 2004.

This result is corroborated with the EPA's RadNet data for Waretown, near the vicinity of Oyster Creek (Attachment B-2). All of the available RadNet results are below the analytical minimum detectable concentration for Sr-90 which is listed as 0.48 pCi/L. For comparison purposes, the EPA's maximum contaminant level (MCL) is 8 pCi/L. The MCL is the concentration above which either treatment or an alternate water source is required for community water systems.

Based on this analysis, the amount of Sr-90 ingested through drinking water is negligible.

Inhalation Pathway

The average actual release rate of Sr-90 from OCNGS from 1972 through 1997 was used to determine how much Sr-90 would be inhaled by a hypothetical maximally exposed pregnant or nursing mother, or infant. The dispersion coefficient for the location of the maximum exposure rate was used to calculate the concentration of Sr-90 in air. It was assumed that the person was outside 24 hours per day with a breathing rate of 1.4 m^3/hr (for the adult) and 0.19 m^3/h for the infant[13]. The resultant Sr-90 activity inhaled is 2.25E-5 pCi/day for the adult and 3.0E-6 for an infant, which is 100 and 10,000[14] times lower respectively, than the derived ingestion rate of Sr-90 in milk for an adult and infant associated with releases from OCNGS. Based on this analysis, the amount of Sr-90 inhaled is negligible compared to that ingested from milk.

Conclusion

The analyses presented in this appendix would seem to strongly indicate that, any Sr-90 in the teeth, bone, or soft tissue of adults, children, infants, or a developing fetus, in the vicinity of Oyster Creek, are due to residual levels of fallout radionuclides in the environment, and not from routine airborne emissions from Oyster Creek.

[13] Exposure Factors Handbook Volume I, US Environmental Protection Agency, EPA/600/P-95/002Fa, May, 1989, p 5-24.

[14] The ingestion rate of milk for infants is 3 times that of adults.

Table B-1

Sr-90 in Milk in New Jersey

Location: **NJ**
Medium: **PASTEURIZED MILK**
Nuclides/Radiation: **Sr-90**
Units: **Traditional**
Year Date Range : **1960 – 2004**

Location	Medium	Sample Date	Procedure Name	Nuclides/Radiation	Result	Combined Standard Uncertainty	MDC	Unit
TRENTON, NJ	PASTEURIZED MILK	15-JUN-60		Stromtium-90	10	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JUL-60		Strontium-90	8	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-AUG-60		Strontium-90	7	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-SEP-60		Strontium-90	7	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-OCT-60		Strontium-90	8	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-NOV-60		Strontium-90	10	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-DEC-60		Strontium-90	6	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JAN-61		Strontium-90	6	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-FEB-61		Strontium-90	6	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-MAR-61		Strontium-90	9	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-APR-61		Strontium-90	8	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-MAY-61		Strontium-90	8	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JUN-61		Strontium-90	10	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JUL-61		Strontium-90	8	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-AUG-61		Strontium-90	8	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-SEP-61		Strontium-90	8	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-OCT-61		Strontium-90	8	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-NOV-61		Strontium-90	10	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-DEC-61		Strontium-90	8	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JAN-62		Strontium-90	8	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-FEB-62		Strontium-90	9	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-MAR-62		Strontium-90	8	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-APR-62		Strontium-90	8	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-MAY-62		Strontium-90	11	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JUN-62		Strontium-90	12	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JUL-62		Strontium-90	10	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-AUG-62		Strontium-90	9	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-SEP-62		Strontium-90	18	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-OCT-62		Strontium-90	14	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-NOV-62		Strontium-90	16	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-DEC-62		Strontium-90	8	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JAN-63		Strontium-90	14	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-FEB-63		Strontium-90	10	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-MAR-63		Strontium-90	14	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-APR-63		Strontium-90	19	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-MAY-63		Strontium-90	25	2.5	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JUN-63		Strontium-90	33	3.3	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JUL-63		Strontium-90	32	3.2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-AUG-63		Strontium-90	25	2.5	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-SEP-63		Strontium-90	22	2.2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-OCT-63		Strontium-90	19	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-NOV-63		Strontium-90	18	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-DEC-63		Strontium-90	19	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JAN-64		Strontium-90	20	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-FEB-64		Strontium-90	17	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-MAR-64		Strontium-90	18	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-APR-64		Strontium-90	18	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-MAY-64		Strontium-90	25	2.5	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JUN-64		Strontium-90	25	2.5	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JUL-64		Strontium-90	23	2.3	2	pCi/L

Location	Medium	Sample Date	Procedure Name	Nuclides/Radiation	Result	Combined Standard Uncertainty	MDC	Unit
TRENTON, NJ	PASTEURIZED MILK	15-AUG-64		Strontium-90	16	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-SEP-64		Strontium-90	16	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-OCT-64		Strontium-90	14	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-NOV-64		Strontium-90	17	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-DEC-64		Strontium-90	14	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JAN-65		Strontium-90	14	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-FEB-65		Strontium-90	18	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-MAR-65		Strontium-90	16	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-APR-65		Strontium-90	16	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-MAY-65		Strontium-90	15	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JUN-65		Strontium-90	16	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JUL-65		Strontium-90	16	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-AUG-65		Strontium-90	14	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-SEP-65		Strontium-90	12	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-OCT-65		Strontium-90	11	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-NOV-65		Strontium-90	11	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-DEC-65		Strontium-90	12	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JAN-66		Strontium-90	10	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-FEB-66		Strontium-90	14	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-MAR-66		Strontium-90	11	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-APR-66		Strontium-90	14	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-MAY-66		Strontium-90	11	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JUN-66		Strontium-90	14	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JUL-66		Strontium-90	12	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-AUG-66		Strontium-90	11	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-SEP-66		Strontium-90	10	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-OCT-66		Strontium-90	10	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-NOV-66		Strontium-90	10	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-DEC-66		Strontium-90	11	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JAN-67		Strontium-90	10	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-FEB-67		Strontium-90	10	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-MAR-67		Strontium-90	10	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-APR-67		Strontium-90	10	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-MAY-67		Strontium-90	10	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JUN-67		Strontium-90	11	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JUL-67		Strontium-90	10	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-AUG-67		Strontium-90	9	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-SEP-67		Strontium-90	10	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-OCT-67		Strontium-90	9.6	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-NOV-67		Strontium-90	11	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-DEC-67		Strontium-90	8	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JAN-68		Strontium-90	9	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-FEB-68		Strontium-90	8	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-MAR-68		Strontium-90	8	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-APR-68		Strontium-90	14	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-MAY-68		Strontium-90	9	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JUN-68		Strontium-90	15	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JUL-68		Strontium-90	12	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-AUG-68		Strontium-90	11	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-SEP-68		Strontium-90	8	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-OCT-68		Strontium-90	6	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-NOV-68		Strontium-90	9	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-DEC-68		Strontium-90	10	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JAN-69		Strontium-90	9	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-FEB-69		Strontium-90	7	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-MAR-69		Strontium-90	8	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-APR-69		Strontium-90	9	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-MAY-69		Strontium-90	9	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JUN-69		Strontium-90	10	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JUL-69		Strontium-90	9	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-AUG-69		Strontium-90	13	2	2	pCi/L

Location	Medium	Sample Date	Procedure Name	Nuclides/Radiation	Result	Combined Standard Uncertainty	MDC	Unit
TRENTON, NJ	PASTEURIZED MILK	15-SEP-69		Strontium-90	9	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-OCT-69		Strontium-90	9	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-NOV-69		Strontium-90	8	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-DEC-69		Strontium-90	7	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JAN-70		Strontium-90	8	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-FEB-70		Strontium-90	10	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-MAR-70		Strontium-90	7	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-APR-70		Strontium-90	0	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-MAY-70		Strontium-90	8	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JUN-70		Strontium-90	8	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JUL-70		Strontium-90	11	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-OCT-70		Strontium-90	8	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JAN-71		Strontium-90	7	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-APR-71		Strontium-90	10	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JUL-71		Strontium-90	9	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-OCT-71		Strontium-90	7	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JAN-72		Strontium-90	6	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-APR-72		Strontium-90	8	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JUL-72		Strontium-90	6	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-OCT-72		Strontium-90	7	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JAN-73		Strontium-90	6	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-APR-73		Strontium-90	6	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JUL-73		Strontium-90	4	2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JUL-75		Strontium-90	5.7	1.6	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JUL-76		Strontium-90	4	1	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	22-OCT-76		Strontium-90	5	0.5	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	01-NOV-76		Strontium-90	7.5	0.9	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JUL-77		Strontium-90	5.1	1.2	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	03-OCT-77		Strontium-90	4.4	0.8	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	11-OCT-77		Strontium-90	6.6	1	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	17-OCT-77		Strontium-90	4.1	0.7	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	15-JUL-78		Strontium-90	4.8	1.3	2	pCi/L
TRENTON, NJ	PASTEURIZED MILK	20-JUL-79	Strontium	Strontium-90	4.6	0.5	---	pCi/L
TRENTON, NJ	PASTEURIZED MILK	11-JUL-80	Strontium	Strontium-90	4.59	0.68	---	pCi/L
TRENTON, NJ	PASTEURIZED MILK	09-JUL-81	Strontium	Strontium-90	4.58	0.6	---	pCi/L
TRENTON, NJ	PASTEURIZED MILK	01-JUL-82	Strontium	Strontium-90	3.41	0.57	---	pCi/L
TRENTON, NJ	PASTEURIZED MILK	07-JUL-83	Strontium	Strontium-90	4.28	0.45	---	pCi/L
TRENTON, NJ	PASTEURIZED MILK	05-JUL-84	Strontium	Strontium-90	2.36	0.63	---	pCi/L
TRENTON, NJ	PASTEURIZED MILK	10-JUL-85	Strontium	Strontium-90	2.54	0.19	---	pCi/L
TRENTON, NJ	PASTEURIZED MILK	06-MAY-86	Strontium	Strontium-90	3	0.68	---	pCi/L
TRENTON, NJ	PASTEURIZED MILK	01-JUL-86	Strontium	Strontium-90	-0.2	0.23	---	pCi/L
TRENTON, NJ	PASTEURIZED MILK	08-JUL-87	Strontium	Strontium-90	3	0.18	---	pCi/L
TRENTON, NJ	PASTEURIZED MILK	06-JUL-88	Strontium	Strontium-90	1.84	0.49	---	pCi/L
TRENTON, NJ	PASTEURIZED MILK	05-JUL-89	Strontium	Strontium-90	1.66	0.75	---	pCi/L
TRENTON, NJ	PASTEURIZED MILK	03-JUL-90	Strontium	Strontium-90	2.103	0.064	---	pCi/L
TRENTON, NJ	PASTEURIZED MILK	03-JUL-91	Strontium	Strontium-90	2.16	0.46	---	pCi/L
TRENTON, NJ	PASTEURIZED MILK	09-JUL-92	Strontium	Strontium-90	0.836	0.056	---	pCi/L
TRENTON, NJ	PASTEURIZED MILK	08-JUL-93	Strontium	Strontium-90	1.16	0.3	---	pCi/L
TRENTON, NJ	PASTEURIZED MILK	07-JUL-94	Strontium	Strontium-90	1.44	0.25	0.58	pCi/L
TRENTON, NJ	PASTEURIZED MILK	07-JUL-95	Strontium	Strontium-90	1.26	0.27	0.68	pCi/L
TRENTON, NJ	PASTEURIZED MILK	02-JUL-96	Strontium	Strontium-90	1.55	0.29	0.75	pCi/L
TRENTON, NJ	PASTEURIZED MILK	18-JUL-97	Strontium	Strontium-90	0.75	0.29	0.87	pCi/L
TRENTON, NJ	PASTEURIZED MILK	09-JUL-98	Strontium	Strontium-90	1.13	0.27	0.71	pCi/L
TRENTON, NJ	PASTEURIZED MILK	16-JUL-01	Strontium-89 and 90 in Milk	Strontium-90	1.29	0.27	0.73	pCi/L

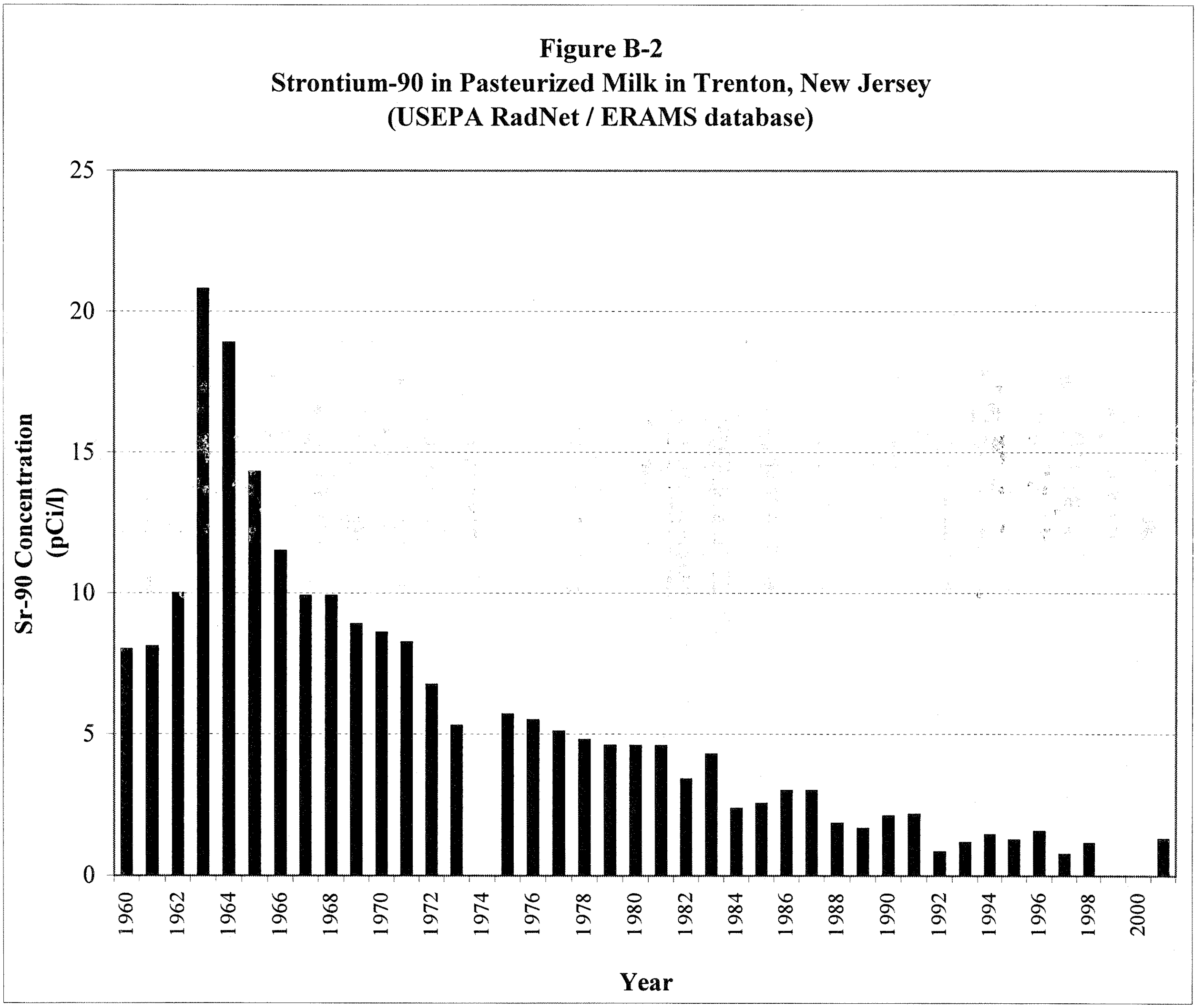

Figure B-2
Strontium-90 in Pasteurized Milk in Trenton, New Jersey
(USEPA RadNet / ERAMS database)
Sr-90 Concentration
(pCi/l)
0
5
10
15
20
25
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
Year

Table B-2

Sr-90 in Drinking Water in New Jersey

Location: **NJ**
Medium: **DRINKING WATER**
Nuclides/Radiation: **Sr-90**
Units: **Traditional**
Year Date Range : **1960 – 2004**

Location	Media	Date Sampled	Radionuclide	Result	Combined Standard Uncertainty	MDC	Units
WARETOWN, NJ	DRINKING WATER	01-JUL-78	Strontium-90	0.04	0.002	---	pCi/L
WARETOWN, NJ	DRINKING WATER	01-JUL-79	Strontium-90	0.1	0.15	---	pCi/L
WARETOWN, NJ	DRINKING WATER	01-JUL-80	Strontium-90	0.02	0.04	---	pCi/L
WARETOWN, NJ	DRINKING WATER	01-JUL-81	Strontium-90	-0.14	0.075	---	pCi/L
WARETOWN, NJ	DRINKING WATER	01-JUL-82	Strontium-90	0.1	0.04	---	pCi/L
WARETOWN, NJ	DRINKING WATER	01-JUL-83	Strontium-90	0.226	0.062	---	pCi/L
WARETOWN, NJ	DRINKING WATER	01-JUL-84	Strontium-90	0.07	0.04	---	pCi/L
WARETOWN, NJ	DRINKING WATER	01-JUL-85	Strontium-90	-0.201	0.067	---	pCi/L
WARETOWN, NJ	DRINKING WATER	01-JUL-86	Strontium-90	0.137	0.041	---	pCi/L
WARETOWN, NJ	DRINKING WATER	01-JUL-87	Strontium-90	0.07	0.18	---	pCi/L
WARETOWN, NJ	DRINKING WATER	01-JUL-88	Strontium-90	-0.036	0.091	---	pCi/L
WARETOWN, NJ	DRINKING WATER	01-JUL-89	Strontium-90	0.113	0.039	---	pCi/L
WARETOWN, NJ	DRINKING WATER	01-JUL-90	Strontium-90	-0.3175	0.00095	---	pCi/L

WARETOWN, NJ	DRINKING WATER	01-JUL-91	Strontium-90	-0.02	0.15	---	pCi/L
WARETOWN, NJ	DRINKING WATER	01-JUL-92	Strontium-90	0.31	0.12	---	pCi/L
Location	Media	Date Sampled	Radionuclide	Result	Combined Standard Uncertainty	MDC	Units
WARETOWN, NJ	DRINKING WATER	01-JUL-93	Strontium-90	-0.034	0.086	0.33	pCi/L
WARETOWN, NJ	DRINKING WATER	01-JUL-94	Strontium-90	0	0.081	0.3	pCi/L
WARETOWN, NJ	DRINKING WATER	01-JUL-95	Strontium-90	0.048	0.084	0.29	pCi/L
WARETOWN, NJ	DRINKING WATER	01-JUL-96	Strontium-90	0.05	0.11	0.38	pCi/L
WARETOWN, NJ	DRINKING WATER	01-JUL-97	Strontium-90	-0.13	0.23	0.85	pCi/L

Appendix C

Glossary of Terms

ADAMS	Agency-wide Documents Access and Management System. The USNRC web-based access tool that enables an individual to search for NRC public documents. Access to ADAMS is through the NRC website at: http://www.nrc.gov/reading-rm/adams/web-based.html
Composite	A collection of more than one sample of the same medium (e.g. milk, air particulate or water) from the same type of media, such that multiple samples can be analyzed as a single sample.
Deciduous teeth	Baby teeth, also known as deciduous teeth, primary or milk teeth are the teeth that children have due to the fact that infant jaws are too small to accommodate adult-sized teeth. These teeth are shed and are followed by secondary or permanent teeth.
Gross Beta	A measurement of all beta activity present, regardless of specific radionuclide source. Gross measurements are used as a method to screen samples for relative levels of radioactivity.
MDC	The Minimum Detectable Concentration is smallest concentration of radioactivity in a sample that can be detected with a 5% probability of erroneously detecting radioactivity, when in fact none was present (Type I error) and also, a 5% probability of not detecting radioactivity, when in fact it is present (Type II error). Often used interchangeably with Minimum Detectable Activity, since the difference between the two terms is only one of units conversion.
NAREL	National Air and Radiation Environmental Laboratory, Samples from the USEPA RadNet / ERAMS program are analyzed at this facility, http://www.epa.gov/narel/
NJBNE	New Jersey Department of Environmental Protection's Bureau of Nuclear Engineering. This group independently monitors radiation in the environment outside the site boundaries of New Jersey's nuclear generating stations (Artificial Island and Oyster Creek).
OCNGS	Oyster Creek Nuclear Generating Station, located in Lacey Township, New Jersey.

Appendix C

Glossary of Terms
(Continued)

RadNet	Formerly known as the ERAMS, RadNet is a national network of monitoring stations that regularly collect air, precipitation, drinking water, and milk samples for analysis of radioactivity. RadNet also documents the status and trends of environmental radioactivity. These data are published by NAREL in a quarterly report entitled *Environmental Radiation Data*. RadNet information can also be found at http://www.epa.gov/narel/radnet/
RPHP	Radiation and Public Health Project - established by scientists and physicians dedicated to understanding the relationships between low-level, nuclear radiation and public health.
USEPA	United States Environmental Protection Agency. The mission of the Environmental Protection Agency is to protect human health and the environment. More information can be found at the USEPA website at: http://www.epa.gov/epahome/aboutepa.htm.
USNRC	U.S. Nuclear Regulatory Commission (NRC) is an independent agency established by the Energy Reorganization Act of 1974 to regulate civilian use of nuclear materials. The NRC is the governing agency of all commercial nuclear power plants in the United States. Information regarding the USNRC may be obtained from their website at: http://www.nrc.gov.